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THE SAULT STE. MARIE WATER POWER CANAL is completed, after four years' work and the expenditure of about $5,000,000. This canal is 2⅓ miles long from the intake to the overflow, and is 224 ft. wide as an average and 22 ft. deep. The entrance is 891 ft. wide and 18 ft. deep, and is estimated to receive a flow of 30,000 cu. ft. per second. At about 1,000 ft. east of the intake the canal proper begins, and at the lower end this canal widens into a forebay for distributing water to the turbines. The power house, on this forebay, is 1,368 ft. long, 100 ft. wide and 125 ft. high, and in it 320 turbines will develop 40,000 I. HP. The electrical equipment includes 80 dynamos. The controlling gate at the head of the canal has four "leaves," 50 ft. long and 28 ft. high, located between piers. The canal was built by the American Soo Power Canal Co., with Mr. F. H. Clergue, President of the Michigan-Lake Superior Co., as the active manager.

THE CHICAGO SANITARY DISTRICT'S WATER power project at Joliet, Ill., has been declared legal by a court decision, but a 60-day injunction has been issued restraining the trustees from proceeding with the work of construction until it has complied with the law by advertising for bids. The suit was brought, it is said, in behalf of the Gaylord syndicate, which proposes to utilize the same water power. It was announced on Aug. 12 that the sanitary trustees would at once advertise for bids for a dam and other water power accessories.

THE TOTAL OF DEVELOPED WATER POWER in France is estimated at 575,000 HP., divided among 40,000 different plants, according to the "Schweizerische Bauzeitung." The total steam power used in the republic, for industrial purposes, transportation, etc., is figured at nearly 7,000,000 HP.

THE CONCRETE AND EARTH DAM AT PROVIDENCE, R. I., built to replace the two earth dams whose failure was described at length in our issue of March 21, 1901, is 353 ft. long, about 24 ft. high above the original surface, and some 6 ft. below that level, has a concrete rollway near the center 34¾ ft. long, and an 18-in. service and 30-in. draw-off pipe through one end of the rollway. The concrete wall does not extend quite the full length of the structure. The wall, 2 ft. wide at the top and about 13½ ft. wide at the base, having batters of ½-in. in 1 ft. on the up-stream, and 4 ins. in 1 ft. on the down-stream side. The down-stream side of the wall is backed from crest to foundation by an earth embankment 6 ft. wide at the top and about 37 ft. wide at the base. The outer slope is 1 on 1½. The concrete is 1:3:6, Portland cement. Two rows of 3-in. hard pine sheeting are driven through sand to a depth of nearly 30 ft. beneath the concrete, one near each toe of the wall. The wet side of the wall is also backed with earth, 1 on 1, but only to about half its height. The surface of water at full pond is 3 ft. below the crest of the dam. Since the failure of the old dam the mill privileges have changed hands and are now owned by the Roger Williams Finishing Co. Mr. Mark W. Schofield, of Providence, was engineer for the dam. Plans, sections and full specifications for the structure are given by Mr. W. C. Simmons, of Providence, State Commissioner of Dams and Reservoirs, in his report for the calendar year 1901.

THE RECEPTION OF WATER FILTRATION BIDS at Washington, D. C., has been "postponed until further notice." Bids were to have been received on Aug. 12 for a slow-sand filtration plant.

A TRAVELING CANTILEVER CRANE will be used for erecting the battleship "Connecticut," to be built at the New York Navy Yard. It will consist of a double truss girder 211 ft. 2½ ins. long over all, with trolley tracks of 20-ft. gage. The trolley travel will be 198 ft., or 99 ft. to each side of the center. The crane girder will travel on a track of 20-ft. gage supported on a steel trestle about 62 ft. high and 513 ft. long over all. The trolley will thus have a clear working space 89 ft. wide and 513 ft. long on each side of the trestle structure. The rise of the hook is 84 ft. 7 ins. The capacity of the crane is 30,000 lbs. at 60 ft. either side of the center and 15,000 lbs. at 99 ft. either side of the center. The power will be sufficient to give a hoisting speed of 125 ft. per minute for a load of 30,000 lbs., or 350 ft. and 700 ft., respectively, for loads of 10,000 and 1,000 lbs. The trolley travel will be 400 to 800 ft. per minute, and the bridge travel 400 to 700 ft., according to load.

A SIX-MASTED STEEL SCHOONER is to be built by the Fore River Ship & Engine Co., of Quincy, Mass. Her principal dimensions will be: Length over all, 339 ft. 6 ins.; length on water line, 306 ft.; beam, 48 ft.; depth, 29 ft. 9 ins.; load draft, 24 ft.; load displacement, 7,700 tons; this will give her a carrying capacity of 5,700 tons. The lower masts will be hollow steel cylinders, and she will spread about 36,000 sq. ft. of canvas. This schooner is being built for the fleet managed by Capt. John G. Crowley, and will be the largest six-master ever built. She will be used as a collier.

THE BOILERS FOR THE BATTLESHIPS "Rhode Island" and "New Jersey," now under construction at the Fore River shipyard, at Quincy, Mass., will be reduced one-half in number by increasing their size. Instead of 24 17 × 14 × 12 ft. boilers, each vessel will have 12 boilers 19 × 14 × 12 ft.

APPLIANCES FOR BURNING OIL FUEL were installed on the steamer "Mariposa," and this vessel has recently returned from a trip between San Francisco and the Society Islands. At the request of Rear-Admiral Melville, Chief of the Bureau of Steam Engineering, Lieut. Ward Winchell, U. S. N., was detailed to accompany this vessel and to make a detailed report of his observations. This report is not yet made public, but promises to be very valuable.

THE DYNAMITE CRUISER "VESUVIUS" is to be sold by the government, or converted into an ordinary gunboat. The "Vesuvius" was built in 1888 under the plans of Capt. Edward Zalinski, U. S. A. She was fitted with three fixed 15-in. tubes, side by side, from which dynamite shells were to be projected by pneumatic power. The ship was the gun-platform and was moved in aiming; the range depended on the charge of air. In her battle trials at Santiago, this ship failed to inflict the damage expected, owing to inaccuracy of fire and lack of range. Her trial speed was over 22 knots, and upon this speed the "Vesuvius" had to depend in getting out of range after firing a shot. As she was loaded with dynamite, a stray hit on the part of the enemy practically meant the destruction of the dynamite cruiser.

THE PUBLIC HEALTH AND MARINE HOSPITAL Service of the United States is the new name given to the old United States Marine Hospital Service by a congressional act, approved July 1, 1902. The head of the service is called the Surgeon-General, and is to have a salary of $5,000 a year. There will be a hygienic laboratory, with divisions of chemistry, zoology, and pharmacology. As often as the Surgeon-General thinks is demanded by "the interests of the public health," but at least once in each year, he shall invite such state and territorial boards of health, quarantine officers and health officers as he sees fit to send not more than one delegate from each state to a sanitary conference; and it shall be his duty to call such a conference on request of not less than five states. One of the most important and promising features of the act is a section designed to aid the movement for uniform vital statistics, as follows:

Sec. 8. That to secure uniformity in the registration of mortality, morbidity and vital statistics it shall be the duty of the Surgeon-General of the Public Health and Marine Hospital Service, after the annual conference required by Section 7 (see above.—Ed.) to be called, to prepare and distribute suitable and necessary forms for the collection and compilation of such statistics, and said statistics, when transmitted to the Public Health and Marine Hospital Bureau on said forms, shall be compiled and published by the Public Health and Marine Hospital Service as a part of the health reports published by said service.

A SEPTIC TANK AND CONTACT BEDS IN A PUBLIC park has been built at Clayton, Mo., for the treatment of the sewage of the court house of St. Louis county. The disposal works cost $2,750 and was constructed by the Cameron Septic Tank Co., Monadnock Block, Chicago.

CABLE RAILWAY CONDUITS AS OPEN SEWERS in St. Louis, Mo., form the subject for complaint from the medical men of that city. They say that certain abandoned cable-conduits, which were regularly cleaned every two weeks when in use, have now become filled with putrifying matter dangerous to health. Electricity has been substituted for the cables, hence the non-use of the conduits.

THE COHOCKSINK RELIEF SEWER AWARD, in Philadelphia, according to the "Public Ledger," of that city, calls for an explanation from the Sewer Department. The contract for this sewer was recently awarded to George A. Vare, at $36 per lin. ft., or for $98,496. Mr. B. J. Sullivan, a civil engineer and a member of the reputable contracting firm of Sullivan Bros., now comes out with a written statement, practically as follows: For this same sewer Sullivan Bros. bid $34.34 per lin. ft. or $93,954.24 for the total sewer; and as a reason for the rejection of their bid they say that they declined to obey "orders" to withdraw from competition. They further state that to cut down the original appropriation of $120,000 for this sewer, the Department of Sewers recently awarded Vare a supplemental contract for $25,000, at the rate of $48 per lin. ft., and this award was made without advertisement or competition. The same George A. Vare received a contract for another portion of the same sewer, at $48 per lin. ft., against a bid of David Peoples aggregating about $26,000 less. Mr. Sullivan properly demands a taxpayers' injunction and an investigation of the awards by the courts. The Sullivan Bros., under a previous administration, built most of the recent large main sewers of Philadelphia, and Mr. B. J. Sullivan was formerly a civil engineer with the Pennsylvania Railway.

REMOVING SEWAGE SLUDGE from settling or septic tanks without drawing off the supernatant liquid is one of two unique features of the Sea Mills sewage disposal works, near Bristol, England. There are three covered tanks, each 12 × 171 ft. in plan, provided with V-shaped scrapers working on an endless wire rope, driven by a gas engine. The scraper has a speed of a little less than 2 ft. per minute, and forces the sludge into a V-shaped discharge channel at one end of the tank, from which it goes to a sludge chamber, and finally to a sludge press. When the scraper reaches the end of the tank "a weight working on a horizontal screw throws the gearing out and the scraper remains stationary" until reversed by the attendant. Before reaching the tanks the sewage flows through a revolving screen, driven by a water wheel with sewage as the motive power. If desired, a chemical precipitant may be mixed with the sewage as it passes over the water wheel, and the tanks used for precipitation. The septicised sewage passes to a storage tank having a capacity of 600,000 Imp. gallons, from which it is discharged into the tidal portion of the River Avon, at high water. A time clock and hydraulic accumulator automatically control the discharge valve, the clock being set daily in accordance with the tide tables. The clock was the joint invention of Messrs. A. P. I. Cotterell, A. M. Hunt and Kemp Bros., and cost about $725. By means of the clock and the mechanical scraper "one qualified man, and a boy to keep him company," are sufficient to operate the disposal works, which serve a present population of about 7,000, under the jurisdiction of the Barton Regis Rural District Council. The information given is taken from a paper read by Mr. Cotterell before the recent Bristol meeting of the Association of Municipal and County Engineers.

THE MOST SERIOUS RAILWAY ACCIDENT of the week was a rear collision on the New York & Long Branch R. R. at Belmar, N. J., on Aug. 19. This line of railroad is operated jointly by the Pennsylvania R. R. and the Central Railroad of New Jersey. A passenger train of the former, bound for New York, had stopped at Belmar to take on passengers when an empty northbound passenger train of the latter road ran into it from behind. In the resulting wreck at least two persons were killed and a number of others injured.

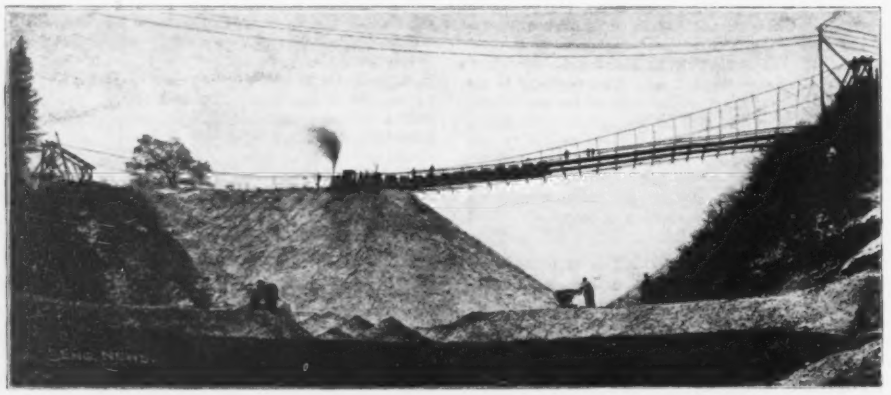
TO ABOLISH GRADE CROSSINGS on the Long Island R. R., the sum of $20,000,000 is said to have been appropriated by the company, the work to be done in conjunction with the local and State authorities.

AMBULANCE CARS are to be maintained at 77 principal German railway stations for the aid of persons injured in train wrecks, by a recent order of the State Railway Administration. Each car will contain a full hospital equipment, including operating tables, and each will be in charge of a medical officer. All railway employes will also be trained in the performance of first-aid duties. The cars will be so located that none will be more than 1½ hours distant from a hospital.

A NOVEL METHOD OF CONSTRUCTING HIGH EMBANKMENTS.

An ingenious method of constructing high earth embankments crossing narrow valleys was employed recently by a Swiss engineer. It is illustrated in the accompanying view, taken from the "Centralblatt der Bauverwaltung." The novelty of the method consists in the use of a light suspension bridge, from which the filling material is dumped directly from railway cars. The following description summarizes the particulars of the case for which this method was devised.

A road in course of construction near Freiburg, in the Swiss canton of Freiburg, was located so



TEMPORARY SUSPENSION BRIDGE USED IN CONSTRUCTING A HIGH EMBANKMENT NEAR FREIBURG, SWITZERLAND.

that it crossed two narrow but unusually deep valleys or ravines. The lengths of crossing were respectively 345 ft. and 360 ft., the maximum depth of fill being 150 ft. and 110 ft. in the two cases. The side slopes of both ravines were quite steep, and the earth embankments which were planned for the crossing could not be practicably constructed by direct haulage with shovels or carts. It seemed necessary to employ trestle falseworks on the line of the fill, and to build the embankment by dumping from the trestles. The great depth of the ravines, however, made this method very costly. In this situation the cantonal engineer in charge of the work, M. Grémaud, conceived the idea of using a light suspension structure in place of a trestle; the comparatively small width of the valleys in question, and the light loads which would come on the bridge—only empty cars—spoke in favor of the scheme, and it was carried into execution, as shown in the view.

The same bridge served successively for both embankments, the more readily as their width was about the same. A very light construction was found sufficient: the cables consisted each of a single wire rope, supported on wooden portal frames about 20 ft. high, and anchored to platforms weighted with stone. The roadway, 13 ft. wide, was of the simplest type, the floor beams suspended by light wire ropes from the cables. The filling was done from one end of the bridge, the engine and the loaded cars being thus always on finished embankment. The deflections of the bridge under its load, sometimes up to 3 ft., were of no consequence to the work, which was carried out very successfully. The cost of the bridge was about $1,600, and the two embankments on which it was used contained an aggregate of 650,000 cu. yds. of fill.

LIQUID FUEL FOR STEAMSHIPS.*

By Edwin L. Orde.†

For many years the Caspian Sea was the only place where liquid fuel was used in the furnaces of marine boilers, and as the quantity available was not sufficient to allow of its export, it could only obtain a very limited application. Of late years, however, the sources of supply have been largely increased in number, and now that the large oil fields of Borneo and Texas are in active operation, and commercial enterprise only needs the stimulus of demand to organize distributing stations, the question of the adoption of liquid fuel on a large scale appears to need for its solution only the close attention of engineers. The principal sources of supply are the fields of Borneo, Burmah, the Caucasus, Texas and California; but there appear to be indications that further supplies exist, and were the demand assured, would be explored and developed.

The crude petroleums as they come from the wells are usually refined by a process of distillation, and the products of the process may be roughly divided into three groups:

1st. Light oils, distilling over up to 150° C.
2d. Illuminating oils, distilling over up to 300°C.
3d. Residuum.

The American light oils consist principally of the members C_6H_{12} to C_8H_{18}, and the illuminating oils C_7H_{16} to $C_{16}H_{34}$ of the Methane series. The residuum can be subjected to higher temperatures when it yields (a) heavy oils which produce lubricating oil and paraffins, and (b) carbon in the form of coke.

The members of the three groups are further subdivided into about 20 for trade purposes. The specific gravities of the three groups are approximately:

Light oils.....0.65 to 0.78 Illuminating oils..0.78 to 0.86
Lubricating oils.0.86 to 0.96

No further consideration of the refining of the crude oils would be necessary were it not for two very distinct processes of distillation, both of which present phenomena which exert an important effect on the behavior of liquid fuel when treated in the burning apparatus.

These are: 1. The "cracking" process. 2. The effect of steam on distillation.

The "cracking" process consists in distilling over the lighter oils at temperatures above those at which they would boil under normal conditions. This is effected either by allowing the products of the distillation to condense and fall back into the contents of the still, or by distilling under pressure. The effect of the process is to decompose the heavier oils remaining in the still and materially decrease their specific gravity. The oil resulting from this process becomes more homogeneous in its composition than before, but, if the temperature in the still reaches too high a point, solid carbon is deposited in the form of coke. These deposits of solid carbon, unless careful attention is paid both to the temperature to which the still is exposed and to its design, form a large proportion of the residuum after the lighter oils have been taken off; and continuous distillation on the "cracking" principle seems to be impossible owing to the rapid increase in quantity.

In the presence of steam, on the contrary, it appears to be possible to distil practically the whole of the crude product. One explanation of this phenomenon that has been given is that steam has the property of lowering the boiling points of the hydrocarbons with which it is brought in contact, and therefore allows them to volatilize at temperatures below those at which the cracking process sets in. Superheated steam is generally used, in order to attain the temperature required for distillation, which reaches 550—600° F. in many cases. Air does not possess this solvent property, nor is it so convenient a vehicle for the heat required in the process of distillation. This part of the subject has been dealt with at some length, as the process of presenting the liquid fuel in boiler furnaces in the most suitable conditions for combustion is in many respects an analogous one. Before complete combustion can take place, the fuel must pass from the liquid to the vapor form, and it is obvious that the most successful apparatus must be that which accomplishes this object with the smallest expenditure of heat. The fuel oils in general use are the crude oils of Borneo and Texas, and the residual oils of the Caucasus and Burmah. The ultimate analysis of these oils is given in Table I.

TABLE I.—Ultimate Analysis of Fuel Oils.

	Percent. of			Calorific value, by Dulong's formula.
	Carbon.	Hydrogen.	Oxygen, etc.	
Borneo	84.8	10.78	1.24	18,[illegible]
Texas	85.66	11.03	3.31	19,[illegible]
Caucasus	84.94	13.96	1.25	18,[illegible]
Burmah	86.4	12.1	1.5	18,[illegible]

It has been suggested by some of the early writers on the subject that liquid fuel has a higher calorific value than solid fuel of the same chemical composition, from the fact that a certain amount of heat has been rendered latent in passing it from the solid to the liquid form; and it has therefore been argued that heat values calculated on the basis of solid carbon are underestimated to the extent of this latent heat of liquefaction. Dr. Paul who investigated the subject very closely has suggested 6,000 B. T. U. as the value of the heat thus lost, but as this is the value assigned by Rankine to the latent heat of the gasification of solid carbon, it would appear to be too high for the latent heat of its liquefaction. The determination of the heat value of petroleum by the bomb calorimeter does not show the existence of this latent heat, and Dr. Paul comes to the conclusion that it is not probable that petroleum, when used as fuel, can be made to evaporate more than about 16 lbs. of water from and at 212° F. This agrees with nearly all the well-authenticated results that are on record.

Taking Borneo oil as an example, some heat balance sheets that have been experimentally obtained are given in Table II.

The heat lost in radiation was measured at a separate trial; the amounts thus found were interpolated in the balance sheet, and found to agree very closely with the results found by difference in the usual way, in all cases but the second when the observed evaporation was undoubtedly too high. The observed evaporation results were 15.4, 15.95, 14.6, and 14.48, respectively. The difference between the first and second pairs of experiments is due to the presence of water in the oil. This exercises a very important function in the behavior of the fuel and is responsible for much of the difficulty that has attended its use. The actual reduction of the heat value of the fuel equals 13.14 B. T. U. per 1% water in addition to the loss

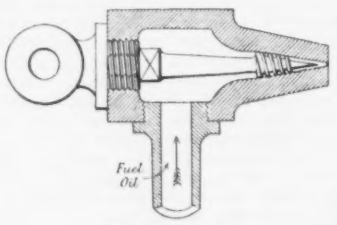


Fig. 1. *Körting.*

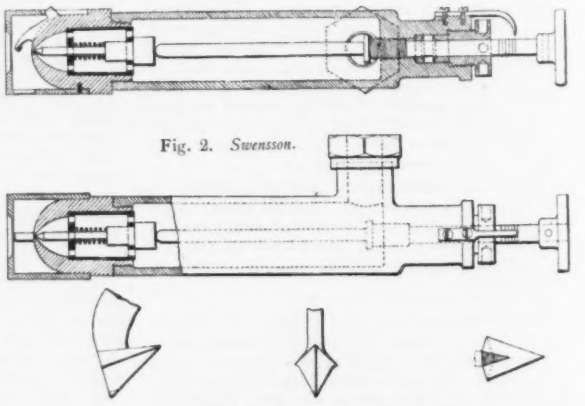


Fig. 2. *Swensson.*

FIGS. 1 AND 2. MECHANICAL SPRAY FUEL OIL FEEDERS FOR BOILER FURNACES.

Enlarged Views of Tongue Sprayer

of the oil which it replaces; for example, 1 lb. of oil mixed with 10% water evolves.

$$18{,}831 \times 0.9 = 16.947.9 - 131.4 = 16{,}816.5 \text{ B.T.U.}$$

a difference of 1,915.5 B.T.U., or a loss in evaporative power of nearly 2 lbs. of water from and at 212°.

Besides this actual loss of heat, the presence of water destroys the conditions necessary for perfect combustion, and this occurs and may cause considerable damage to boilers of the ordinary marine type, although the quantity is not sufficient to extinguish the flame. The first effect is naturally to reduce the temperature of the flames and thereby increase their length, thus moving the point of highest temperature further in to the furnace, which has the effect:

1. Of rendering a large portion of the furnace heating surface entirely useless;
2. Of raising the temperature in the combustion chambers to a point which may be hurtful to the material; and

*Condensed from a paper read before the Institute of Mechanical Engineers.
†Newcastle-upon-Tyne, England.

TABLE II.—Heat Balance Sheet of Borneo Oil.

	Units of evaporation.			
Loss due to moisture. $\frac{10.78}{100} \times 9 \times (212 - t) + 966 + 0.48\ (T - 212)$ (where t = initial temperature of oil; T = temperature of escaping gases.)	1.15	1.0	1.2	1.19
Losses due to heat carried off in escaping gases. $\frac{1 + A^1 \times T}{4{,}000}$ (A = weight of air required for combustion)*	1.46	1.6	2.3	2.21
Loss due to radiation (observed)	1.3	1.4	1.3	1.38
Heat employed in evaporation	15.4	15.4	14.5	14.6
Total heat value of oil	19.4	19.4	19.4	19.4

*Observed.

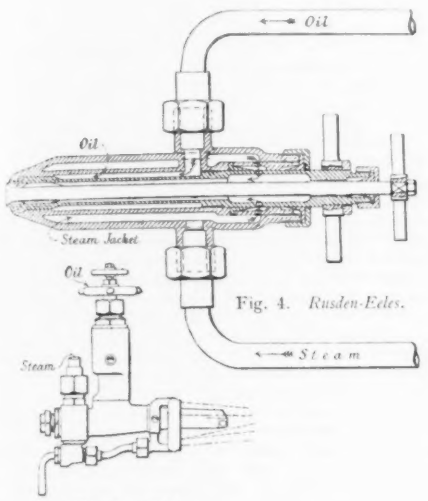


Fig. 3. *Holden.*

Fig. 4. *Rusden-Eeles.*

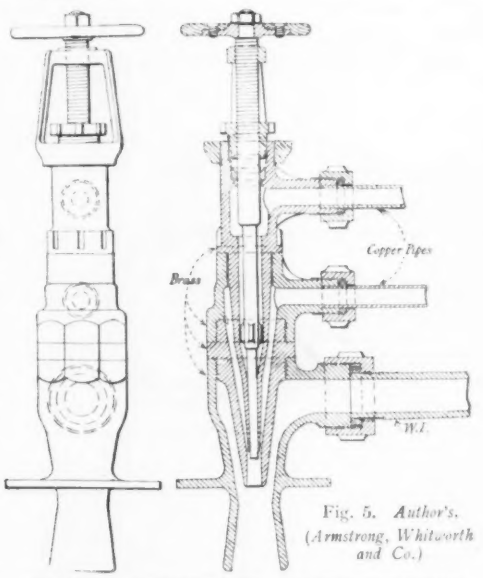


Fig. 5. *Author's.* (*Armstrong, Whitworth and Co.*)

FIGS. 3 TO 5. FUEL OIL FEEDERS USING STEAM OR COMPRESSED AIR FOR SPRAYING.

3. Of causing the last stage of combustion to take place in the smokebox and funnel.

The conditions that attend and the reactions that take place in burning liquid fuel in boiler furnaces present a problem which has apparently not received the attention which it deserves. Petroleum vapor depends entirely on temperature, and it is therefore almost impossible to collect samples when actually burning it in a furnace. It seems obvious that the first effect of the furnace heat on the petroleum spray is to liberate hydrocarbon vapors, and to ignite them on the outer surface of the jet. The ignition raises the temperature of the whole of the jet, and probably dissociates some at least of the hydrocarbon vapors into carbon monoxide and hydrogen. In what form the undissociated hydrocarbon vapors burn it is difficult to conjecture, but the appearance of the flames suggests that acetylene is present. This might conceivably arise from the reaction $CH_4 + CO = H_2O + C_2H_2$. As the temperature of the flame rises, the hydrocarbons are probably all dissociated and burn as CO and H to CO_2 and H_2O without further change. When the conditions are satisfactory, the flames are opaque and dazzling white in color for a distance of some six inches from the nozzle of the burner, become semi-transparent, and almost violet in color at the middle of their length, and shade into red at the end. In burning oil which is mixed with water the combustion is incomplete, the violet color never appears and the end of the flame is dark red and fringed with smoke. In some cases, where water is present in comparatively small quantities, the end of the flame is white and presents the appearance of acetylene, which may arise from want of sufficient heat in the flame to decompose the hydrocarbons. This has been observed, when, although no smoke was formed and the air supply was not more than 20% above what is chemically necessary for the fuel, the evaporative performance of the boiler was poor, which confirms the existence of a low furnace temperature.

The "burners," which have been designed for admitting liquid fuel into boiler furnaces, numerous as they are, may be broadly divided into three distinct types. These are:

1. Mechanical spray in which the liquid fuel is forced under pressure through nozzles, made of such a form as to break it up into a fine spray and thus render it inflammable.
2. Spray burners, where the liquid fuel is held in suspension and driven into the furnace by means of a jet of steam and compressed air.
3. Vapor burners in which the liquid fuel is volatilized and the vapor admitted to the furnace.

So many of these burners have been designed by various inventors that it is impossible to describe more than one or two which are typical of each of these three main divisions, without overstepping the limits of a paper, and in making his selection the author has endeavored as far as possible to treat of those that have stood the test of actual working at sea.

Of mechanical spray burners very few have achieved success. It is obviously very difficult to devise an apparatus which is capable of dividing into a fine spray a material so thick and viscous as fuel oil. The best known and most successful burners of this type are those of Messrs. Körting Bros., Fig. 1. The oil is first heated to a temperature of 130°C. and then forced under a pressure of about 50 lbs. per sq. in. through nozzles, each of which has a small orifice at the apex controlled by a central spindle with an enlargement of spiral form, so arranged as to impart a vortex motion to the oil as it passes through, of sufficient intensity to make it fly into spray by centrifugal force as soon as it issues from the nozzle.

Fig. 6 shows the way in which these burners are generally arranged and the refractory lining to the furnace. Some such arrangement is necessary to maintain the temperature at a sufficiently high point to vaporize the fuel and to prevent condensation of the flame before it has attained the temperature required to ensure complete combustion. Another burner of this type is that of Mr. Swensson, of St. Petersburg, Fig. 2. Here the fuel passes through a minute orifice, and is divided into spray by striking aginst a cutter placed at a short distance from the orifice. An adaptation of the Körting burner is used by Messrs. Howden, who have supplied some installations to boilers fitted with their well-known system of forced draft, Fig. 6.

The second type is by far the best known. Typical examples are: The Holden burner, Fig. 3; the Rusden-Eeles burner, Fig. 4. Both these burners are designed to work with steam as the spraying medium, but in the Holden a current of air is induced by means of a ring of steam-jets outside the flame, which ensures a rapid ignition of the outer layer of the spray, and a central current of air is also induced by the action of the jet of steam and oil passing from the burner.

The Rusden-Eeles burner, Fig. 4, is so well known as not to require a detailed description; it allows of separate adjustment to the steam and oil-jets, and is in all respects a simple and workmanlike fitting.

Fig. 5 shows a burner designed by the author to vaporize as much as possible of the fuel to prevent any possibility of cracking the oil, and at the same time to sweep out in the form of spray any of the heavier products which might remain undistilled. The burner is designed to work with highly superheated steam (preferably 600° F.). The velocity of the jet induces a current of heated air which ensures instant ignition of the outer layers of the flame and consequent increase of temperature over the whole of the jet.

Of vapor burners, pure and simple, the author only knows of one at the present time—the Dürr—Fig. 7. Here there are two reservoirs for containing oil, etc., called by the inventor gasifiers. The smaller gasifiers is heated by means of a fire, and as soon as the oil which it contains is sufficiently heated to give off vapor, this vapor is lighted and the flame serves to heat the large gasifiers, the vapor from which is burnt in the furnace of the boiler to which it is fitted. As soon as this flame is well established, the temperature inside the outer casing covering the two gasifiers is sufficient to maintain the vaporizing process.

In addition to the actual burning apparatus, no installation can be considered complete without (a) some form of filter to cleanse the fuel oil of impurities, and (b) some arrangement for separating water. This last is by no means so simple as it would at first sight appear. The specific gravity of most fuel oils is about 0.92 to 0.96, so that separation by the action of gravity alone is an exceedingly lengthy process and practically never complete; but as the coefficient of expansion of fuel oil is considerably higher than that of water the action may be greatly hastened by heating the contents of the tank; the combination of oil and water however is curiously intimate, and a careful experiment showed that at a temperature of 140° F. seven days elapsed before the water was completely separated. A large expenditure of heat is required if the contents of the fuel tanks are to be maintained at such a temperature, and it is obvious that, unless the separating process is complet and the water is all drained out of the tank before any of the fuel is drawn off for use in the burners, the lower layers, which are the first to flow are formed of a concentrated intermixture of oil and water. One way out of this difficulty consists of a swing pipe supported at one end by a floating vessel. The orifice of the pipe is arranged at a suitable distance below the surface of the liquid fuel, and a coil of steam pipe is fitted so as to raise the temperature of the oil immediately surrounding the opening into the pipe; the fuel passes through the swing pipe on its way to the burners, and is to a great extent freed of water at a comparatively small heat expenditure, Fig. 8.

It is impossible within the limits of a paper to describe

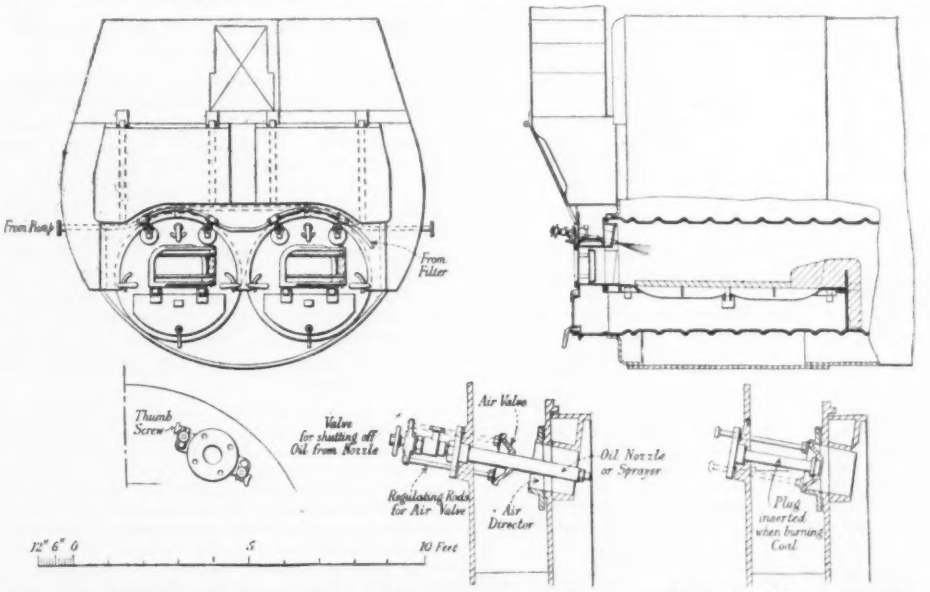


FIG. 6. COMBINED FUEL OIL AND COAL-BURNING APPARATUS IN CONNECTION WITH HOWDEN FORCED DRAFT SYSTEM.

fully the various arrangements that have been designed for burning liquid fuel, and the author would refer those who wish to pursue the subject to the writings of M. Bertin. The actual results obtained by successful installations of burning apparatus on sea-going steamers are somewhat difficult to obtain, but owing to the courtesy of the Shell Transport & Trading Co., The Burmah Oil Co. and Messrs. Körting, the author has been enabled to

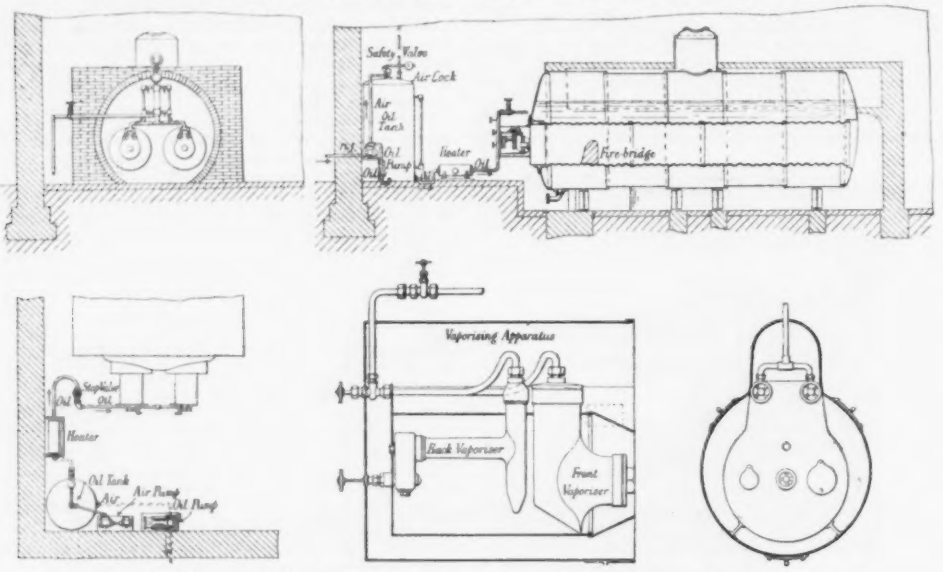


FIG. 7. THE DURR VAPOR FUEL OIL SYSTEM APPLIED TO STATIONARY BOILER.

give figures showing the actual consumption of liquid fuel in practice as exemplified by mechanical and steam spray-burners. It is obviously impossible to draw any exact

Name of ship.	Type burning installation.	Consumption per I. HP. pr hr. in lbs., %.	Corresponding consumption of coal.	Heating surface.	I. HP.
"C. F. Laiesz"	Körting	1.408	1.93	7,560	2,200
"Sithonia"....	Howden	1.065	1.49	.....	2,500
"Murex".....	Rusden-Eeles	1.3? *16 tns	25 tons	5,202	.....
"Syriam".....	Rusden-Eeles	1.32	....	2,480	800
"Khodoung".	The Author . Armstrong .. Whitwrth&Co	1.08	1.67	2,700	960

comparison between solid and liquid fuels without complete trials, carried out in such a way as to show the actual boiler performance, and there are unfortunately no

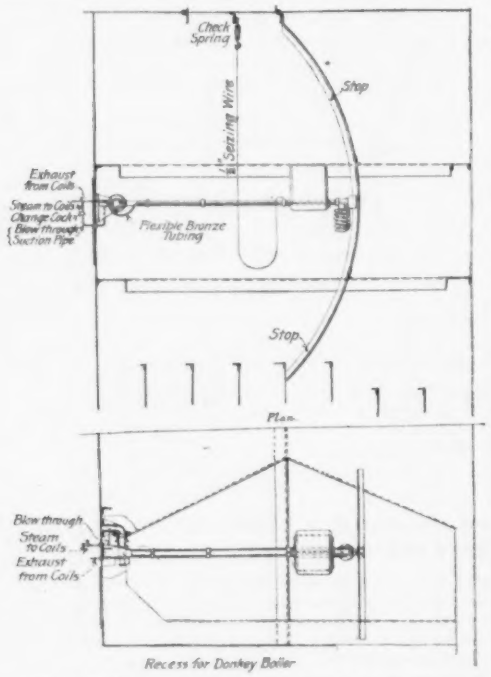


Fig. 8. Water Separator for Fuel Oil Tanks.

available data which allow of this being done properly from a scientific point of view. Commercially, however, the results have some value, and to make the comparison as useful as possible the corresponding consumption of coal as actually ascertained is given in four cases.

Differences in consumption in favor of liquid fuel as compared with coal:

"C. F. Laiesz"...say 27.0% "Murex".....36.0%
"Sithonia".....28.6% "Khodoung" 35.5%

All the vessels have triple-expansion engines of normal proportions, except the "Sithonia," in which quadruple expansion machinery is fitted, and from the coal consumption trial the amount of water required per I. HP. must be considerably less than in the other vessels referred to.

From the figures given above, it is evident that with a well-designed apparatus it is possible by good management to realize in actual practice the full difference in calorific value between liquid and solid fuel, at rates of evaporation such as are usually obtained in the boilers of vessels of the mercantile marine. At the higher rates of evaporation, such as required in war vessels, the problem becomes more complex, but now that it is receiving the serious consideration of the Admiralty, there can be no doubt that a satisfactory solution of this most important question will be arrived at.

*The consumption in this case is given in tons per day From Sir Fortescue Flannery's paper in the "Transactions of the Institution of Naval Architects, 1902," No I. HP. was given.

PROGRESS ON THE NEW EAST RIVER BRIDGES AT NEW YORK CITY.

The East River Bridges now under construction at New York city are reported upon briefly by Mr. Gustav Lindenthal, M. Am. Soc. C. E., Commissioner of Bridges, in the report of the Department of Bridges for the six months ending June 30, 1902. By ordinance of the Board of Aldermen the names of the four bridges across the East River, beginning at the old New York and Brooklyn Bridge, have been made as follows: Brooklyn Bridge, Manhattan Bridge, Williamsburg Bridge and Blackwell's Island Bridge. The bridges now under construction are the Manhattan, Williamsburg and Blackwell's Island, and Commissioner Lindenthal reports as follows respecting these three structures:

WILLIAMSBURG BRIDGE.—On Jan. 1, 1902, only 5% of the cable wires had been strung. On June 30, 1902, all of the cable wires had been strung and adjusted in place, and the wires are now being grouped together into compact cylindrical form in each cable. A large number of the cable bands have been made, and much of the suspender wire, a few of the cable bands and some of the suspenders have been delivered. All of the steel work of the Brooklyn approach has been erected except the buckle plate flooring and the railing, on which good progress is now being made. All of the foundations for the Manhattan approach have been completed, the terminal masonry is well under way, and a fair start has been made upon the erection of the steel work. The greater portion of the steel work still remains to be manufactured in the shops. Nearly one-third of the steel for the suspended span has been delivered at the mills, but none of it has been manufactured. The Pennsylvania Steel Co., which has the contract for all the remaining steel work, is required by contract to finish its work within eight months after the cables and suspenders therefrom are finished. The cables and suspenders are expected to be ready from present indications by Sept. 1. I have received from the Pennsylvania Steel Co. strong assurances that they will finish their contract within the eight months; that is, before June 1, 1903. Thereafter about three months are required for completing the roadways, so that the completion of the bridge may be looked for by Oct. 1, 1903, barring unforeseen delays. The working out of the architectural features of this bridge has been placed in the hands of Mr. Henry F. Hornbostel, architect, who will also furnish the plans for the necessary rooms required for toll collectors and for purposes of storage, toilet and shelter, for which no provision was made in the original plans. It would also be very desirable to make the roadway between the anchorages entirely fireproof—by means of buckle plate and asphalt flooring—instead of the wooden flooring provided in the original plans. On the Brooklyn Bridge, which has a wood flooring, a number of fires have occurred which have been put out promptly. Experience there teaches the necessity of providing a better and more fireproof construction on all new and important bridges. A fire would not only cause damage by warping of the iron work, but it might eventually heat the cables and impair their strength—a most fatal effect if it should happen to a structure of such cost as this one.

MANHATTAN BRIDGE.—This bridge will probably be the most important avenue between the boroughs of Manhattan and Brooklyn, as it is intended that the Manhattan approach on Canal St. shall be on a line to the North River, and intersect all transportation lines running north and south in Manhattan. This bridge will lie on the main route from the heart of Manhattan to the Atlantic Ocean, and through the heart of Brooklyn.

The plans for this bridge originally contemplated four wire cables, in combination with four stiffening trusses. In view of the fact that wire cables have proved to be a source of great delay in construction of the Williamsburg Bridge, and also with a view to greater economy, the plans for this bridge were revised, so that cables may be used of forged eye-bars of a high-grade steel, in combination with a more effective system of stiffening, from which greater economy in construction (and thereafter in maintenance) will result. Based on the experience with passenger transportation over the Brooklyn Bridge, the Manhattan Bridge (which will be its nearest neighbor) will have eight tracks in two stories; the upper story to have four tracks, instead of the former two, for elevated railroads, and the lower four tracks for trolley cars or moving platforms, as later exigencies may decide. In addition, there will be a wide roadway and two promenades. The structure will also be made fireproof throughout, the roadways to be constructed of buckle plates and asphaltum.

As the architectural and aesthetic features of the bridge require the approval of the Municipal Art Commission (under Section 637 of the Revised City Charter), the plans for the same will be submitted to the said commission within the next few weeks. No details of the superstructure had been definitely adopted for this bridge previous to those now studied. The revised plans will involve for the increased capacity no greater cost of construction than the original general plans.

Only one contract was made (and that for only one tower foundation of this bridge, located at the foot of Washington St., Brooklyn), the amount of the contract being $471,757. This contract was let on May 1, 1901. The caisson foundation is being sunk by the compressed air method, and it has now reached a depth of 85 ft., or within 9 ft. of bedrock. The progress of this work has been especially free from accidents. Three men were slightly injured and one seriously. Of the few cases of "caisson disease," one only was fatal. The surveys for this bridge required much painstaking and time-consuming work, the true property lines, particularly in Brooklyn, not being correctly recorded. The preparation of the damage map requires the making of original surveys. For reasons of economy and greater speed in construction, it would be preferable to let (after the remainder of the substructure work—consisting of the New York tower foundation and pier and of the two anchorages—has been contracted for) in one contract the construction of the steel towers and entire superstructure, including the chain cables. This will have the great advantage of eliminating delays such as occur from a number of separate and independent contracts for different parts of the superstructure.

BLACKWELL'S ISLAND BRIDGE.—The original plans for this bridge provided that the superstructure should have a width of 120 ft. The plans have been revised, so as to reduce the width to 80 ft., without in any way decreasing the capacity of the bridge, for it will then accommodate four trolley tracks, two elevated railroad tracks, one wide roadway and two promenades, and also to make the bridge fireproof, no wood to be used for the roadway or elsewhere. In the original plans no provision had been made for reaching Blackwell's Island, either by stairways or by elevators. The Department of Charities and also that of Correction have urgently asked for that accommodation, both departments having important institutions located on that island, which can be reached only by water and in the daytime. The revised plans provide for stairways and elevators to the island, also for the necessary shelter rooms for toll collectors and storage rooms on the two anchorage piers. These added features necessitated certain changes of detail in all six piers. As the architectural and aesthetic features of the plans require the approval of the Municipal Art Commis-

sion, the plans will be submitted to the said commission; and as the revised plans will require a smaller amount of land and property, they will also be laid before the Board of Estimate and Apportionment and Board of Aldermen for approval.

A contract for the six masonry piers of this bridge was let to Ryan & Parker on June 27, 1901, at a cost of $745,547. Actual construction began late in September, 1901. Very little of the work had been done by Jan. 1, 1902, as the cost for the same did not then exceed $42,000. Recently the work has progressed more rapidly, but pending the approval of the plans by the Municipal Art Commission, a suspension on the work for the upper part of the piers was ordered on June 23, 1902. The contractors have not begun work yet on two of the six piers, inasmuch as the land upon which they are to be erected has not yet been acquired by the city. The changes in the masonry work as contracted for are only those of detail and considered to be within the scope of the existing contracts. The masonry work required for the elevators and stairway housings to be added to the two piers on Blackwell's Island will be a separate work, for which tenders will be invited at the proper time.

PONTOON FOOT BRIDGE OVER THE CHICAGO RIVER.

The removal of the old swing bridge over the Chicago River at State St. to make room for the new Scherzer bascule bridge at this site has seriously interfered with traffic on this busy thoroughfare, and it has been decided to erect a temporary foot bridge for the convenience of the people and to prevent congestion of traffic at the other bridges. Several plans were proposed, but eventually the design of a pontoon bridge was selected by the Sanitary District, which is building all the new bridges over the river. This design was submitted by Roemheld & Gallery, contracting engineers, 719 Chamber of Commerce Building, Chicago, and to them we are indebted for plans of the temporary bridge.

The bridge consists of two parallel-chord timber trusses, 117 ft. long over end panels, 12 ft. deep c. to c. of chords, and spaced 11 ft. apart c. to c. of trusses. The trusses have 9-ft. panels and are connected by top and bottom lateral bracing. The clear width is 10 ft., and the floor consists of a single layer of 2-in. plank, laid longitudinally, and carried by floor joists 2 × 10 ins., spaced 2 ft. c. to c. The bridge is designed for a live load of 80 lbs. per sq. ft. One end of the bridge rests upon a pile pivot pier, while the other end is carried by a timber pontoon. It is operated by a 15-HP. motor placed on the pontoon and driving a crab, round the drum of which is wound a chain whose ends are anchored at opposite sides of the river. When the bridge is open for traffic it gives a waterway of 60 ft., and a headway of 16 ft., which is sufficient for tugs and barges. When swung open for navigation it gives a clear waterway of 100 ft.

The pivoted end of the bridge has a pair of oak bolsters, 12 × 12 ins., extending under the bottom chords; to the middle of these is attached the upper center plate, while their ends carry two conical wheels 12 ins. diameter and 6 ins. wide on the face. By having these wheels in transverse line with the center pin, the free end of the bridge can rise and fall with the stage of the water without causing any distortion in the relations of the rolling gear, or any vertical racking strains in the trusses. The wheels run on 8-in. track plates spiked to the top timbers of the pier, and to these timbers is also bolted the lower center casting for the 4-in. center pin or pivot. An iron ring ¾ × 3 ins. encircles this casting, and to it are attached diagonal rods leading to the trusses, by which (as well as by timber braces between the trusses and bolster) the trusses are kept in proper relation to the pivot. These details are shown in Fig. 2.

The pontoon is 38 × 20 ft. on top and 20 × 20 ft. on the bottom; it is 7 ft. deep, but drawing only about 24 ins. of water when loaded. It consists essentially of three 38-ft. trusses, the middle one of heavy construction (carrying the greater part of the load) and the side trusses somewhat lighter. Across the top, bottom and sides of the trusses are 6-in. timbers to which is spiked the sheathing of 2 × 10-in. pine plank. Two trestle bents upon the pontoon carry transverse caps, upon which rest the bottom chords of the bridge trusses. The electric motor and winding drum are mounted in a cabin on the deck of the pontoon. The bridge can be opened or closed in about 45 seconds.

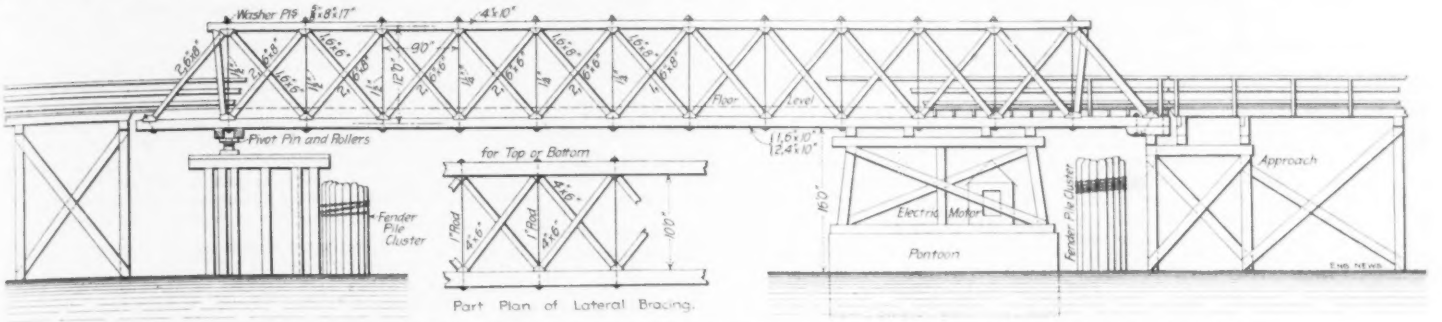


FIG. 1. PONTOON FOOTBRIDGE OVER THE CHICAGO RIVER. Roemheld & Gallery, Chicago, Engineers and Builders.

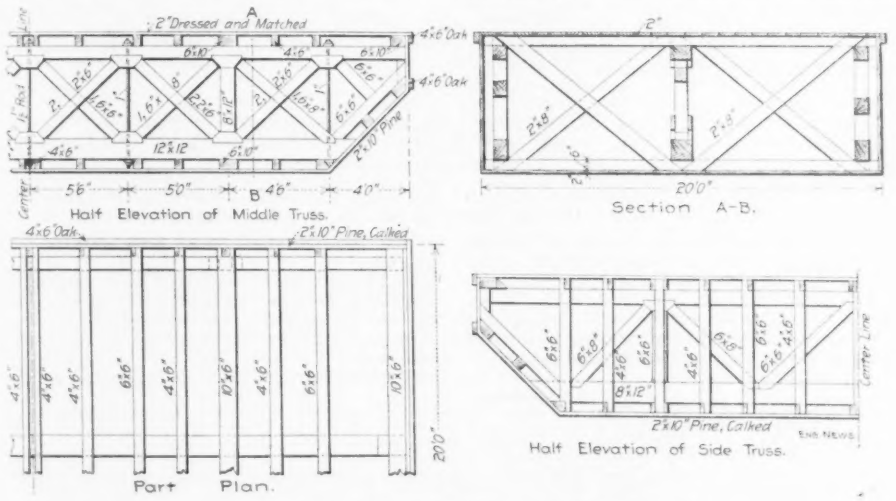


FIG. 3. PONTOON FOR CHICAGO RIVER BRIDGE.

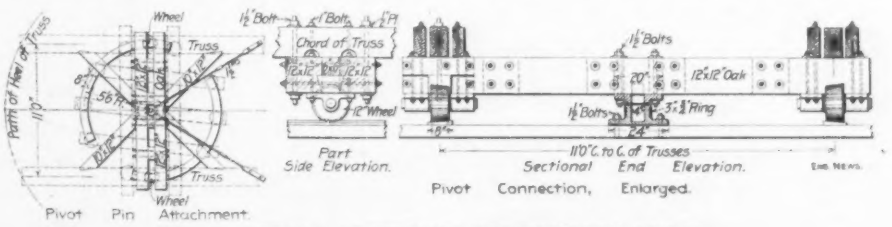


FIG. 2. DETAILS OF TRUSSES FOR PONTOON BRIDGE.

TESTS TO DETERMINE EFFECT OF REHEATING AND HIGH VACUUM ON STEAM ENGINE ECONOMY.*

By R. L. Weighton.†

The object of this paper is to record the results of two separate sets of experiments bearing upon the economical performance of the steam engine. Both sets of experiments were made upon the experimental engines in the engineering laboratory at the Durham College of Science, Newcastle-upon-Tyne, and form part of a systematic course of research work upon the steam engine which is being carried out there.

I. ECONOMICAL EFFECT OF RECEIVER REHEATING.

METHOD OF MAKING THE TRIALS.—The cylinders used for these trials were 7 ins. and 15½ ins. diameter, with a stroke of 18 ins. The boiler pressure was maintained constant throughout the trials at 200 lbs. per sq. in. above the atmosphere. The reheater, which was specially fitted to the engines for the purpose of these trials, was fitted to the engines as shown in Fig. 1. The heating surface consisted of a double coil of copper piping arranged inside a cast-iron chamber, and amounted to 30 sq. ft. The piping was 1¼ ins. external diameter and 1.06 ins. internal diameter. The receiver steam was compelled to pass through the heater by the blocking up of the middle cylinder and ports, as indicated in the drawing. Steam of boiler pressure was admitted to the inside of the heater coils. The water condensed in these coils passed to a trap at a lower level, in which it was carefully measured, and from which it was periodically drained off, thus keeping the coils absolutely clear of water. The receiver condensation was similarly dealt with.

In order to test the effect of the reheating at different loads, the power of the engines was varied, and a progressive series of results was obtained. The power variation was brought about by variation in the cut-off in the high-pressure cylinder, the low-pressure cut-off remaining constant throughout at 7 ins.

The engines are normally fitted with Meyer's expansion valves, but it so happened that prior to these trials, and for other purposes, the high-pressure cylinder had been fitted with a shifting eccentric, in imitation of the action of an automatic expansion governor. This eccentric was retained for the reheating trials, and was shifted by hand to give the variation in power. There was no governor attached to the engines. To preserve as great a uniformity of conditions as possible, the experiments were made in pairs, the only change between the two trials of each pair being that in the one the steam was shut off from the reheater coils, while in the other the steam was

*A paper read before the Institution of Mechanical Engineers of Great Britain.

†Professor in Durham College of Science, Newcastle-on-Tyne, England.

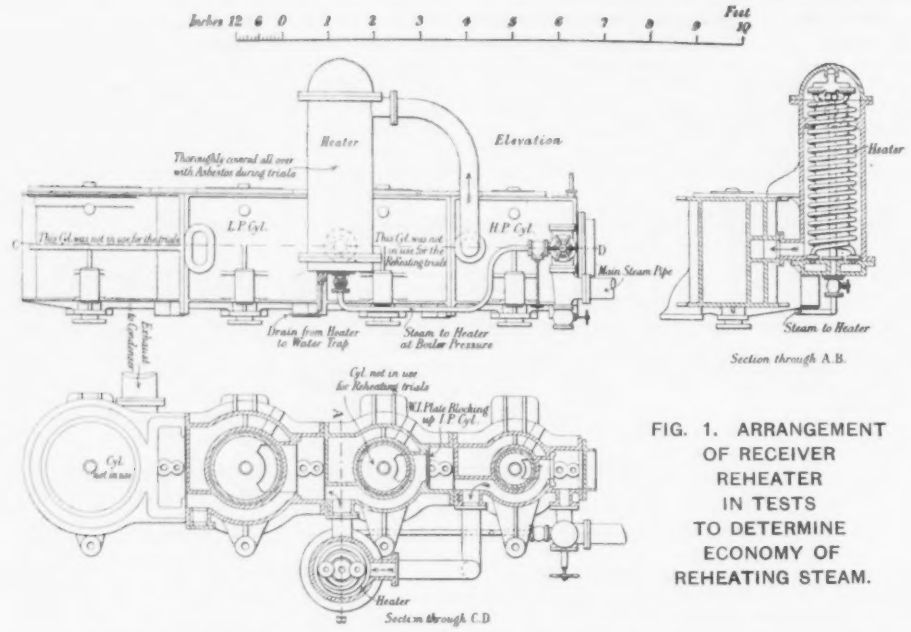

Inches 12 6 0 1 2 3 4 5 6 7 8 9 Feet 10
Heater
Elevation
Thoroughly covered all over with Asbestos during trials
L.P. Cyl.
H.P. Cyl.
This Cyl. was not in use for the trials
This Cyl. was not in use for the Reheating trials
Main Steam Pipe
Exhaust to Condenser
Drain from Heater to Water Trap
Steam to Heater at Boiler Pressure
Heater
Steam to Heater
Section through A.B.
Cyl. not in use for Reheating trials
M.I. Plate Blocking up I.P. Cyl.
Cyl. not in use
Heater
Section through C.D

FIG. 1. ARRANGEMENT OF RECEIVER REHEATER IN TESTS TO DETERMINE ECONOMY OF REHEATING STEAM.

admitted to the coils. Sufficient intervals were allowed to elapse between the trials to permit of the attainment of thermodynamic stability under the changed conditions. In this way only has the author found it possible to obtain consistent results in any series of experiments where the differences in effect due to given changes in conditions are small.

The dynamometer was adjusted to give as nearly as possible 133 revolutions per minute for the first trial of a pair, the steam being shut off from the heater coils and the receiver steam passing through the heater on its way to the low-pressure cylinder. Under these conditions a trial was run, and the observations and measurements recorded. Immediately on finishing, steam was admitted to the reheater coils, and the engines allowed to run till they adjusted themselves to the new conditions, no other change whatever being made as compared with the trial just completed. The vacuum was kept as nearly as possible constant throughout all the trials.

RESULTS OF THE TRIALS.—The results are given in Table I., and are recorded graphically in Fig. 2. Attention is directed to the following points in these results:

1. The amount of condensation per hour in the heater coils seems to be independent of the difference of temperature between the heating and the heated steam, and would appear to depend chiefly upon the quantity of heated steam (exhaust from high-pressure cylinder) passing through the heater in unit time. It will be noticed from the table that as the power diminishes so does the quantity condensed in the coils diminish, and this in spite of the fact that the temperature difference increases as the power grows less.

2. The influence of the reheater is very marked in respect of the following, namely: (a) Reducing the amount of condensation in the receiver; (b) raising the receiver pressure; (c) raising the mean pressure throughout the engines; (d) increasing the speed of revolution of the engines; (e) increasing the dryness of the steam acting in the low-pressure cylinder.

These may be ranked as effects which are in themselves favorable to the attainment of economy.

3. The influence of the reheater is, however, equally marked in effects which are detrimental to economy, namely: (a) Lowering the mechanical efficiency of the engines; (b) increasing the steam consumption per horse-power developed.

From the last two columns of Table I. it is seen that at all powers there is a slight loss attendant on the use of the reheater, with the single exception of "water per I. H-P.," Trial X.

The consumption per B. H-P. is in all cases consistently greater when the heater is in use, the average increase being 2.6% against the heater. The economic effect of the heater in terms of water per I. H-P. is exceedingly small, an average of 0.18% against the heater. The smallness here, however, is entirely due to Trial X, already referred to. The effect, at any rate in terms of brake horse-power, is appreciable and definite, and this effect—as compared with that in terms of indicated horse-power—is almost entirely due to the detrimental influence of the reheater upon mechanical efficiency. It will be noticed from the table that in every case a lower mechanical efficiency is associated with the use of the reheater, the average adverse effect being 2.2%. The cause of this very undesirable effect is doubtless to be found in the greater dryness of the working steam after passing through the reheater, when steam is in the coils. The result here obtained shows the necessity for stating steam engine efficiency in terms of brake horse-power, instead of indicated horse-power, especially in those cases in which steam drying arrangements or devices are employed, e. g., steam jackets, superheaters, etc.

II. ECONOMICAL EFFECT OF DEGREE OF VACUUM.

METHOD OF MAKING THE TRIALS.—For these trials the cylinders were arranged as triple-expansion, having diameters of 7, 10½, 15½ ins., with 18 ins. stroke. The boiler pressure employed was 150 lbs. above the atmosphere, and the cut-off in each cylinder was retained throughout at 10½ ins. The brake adjustment was unchanged during the trials, so that any variation in speed of revolution of the engines was entirely due to variation in the vacuum. The degree of vacuum was the one and only condition which was varied throughout the trials, this variation being brought about by variation in the quantity of condensing water. Any degree of vacuum up to the maximum was obtainable by this means. In the case of no vacuum at all, the air-pump was disconnected, and the feed-water simply allowed to run out into the measuring tanks, sufficient condensing water being supplied in this case to just prevent the pressure in the condenser from rising about that of the atmosphere.

The receivers were kept clear of water by drainage at intervals into the hot-well, and it is owing to this drainage that the hot-well temperature was slightly in excess of the temperature corresponding to the condenser vacuum.

RESULTS OF THE TRIALS.—The general results are

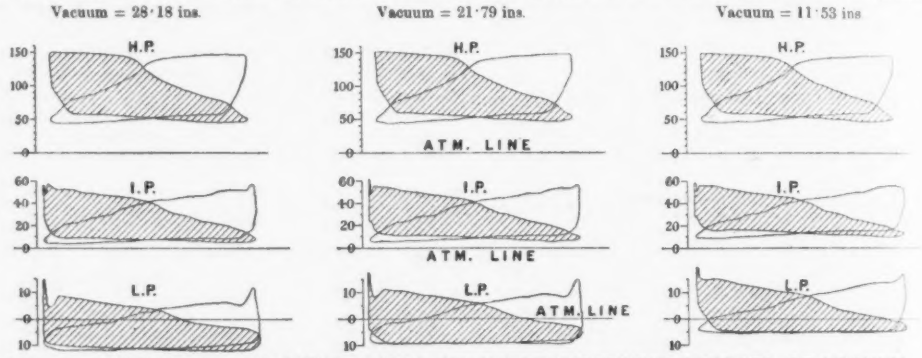


FIG. 4. SAMPLES OF INDICATOR CARDS AT THREE DIFFERENT DEGREES OF VACUUM.
(Cylinders, 7 ins., 10½ ins., 12½ ins. Stroke, 18 ins. Cut-off, 10½ ins. in each cylinder.)

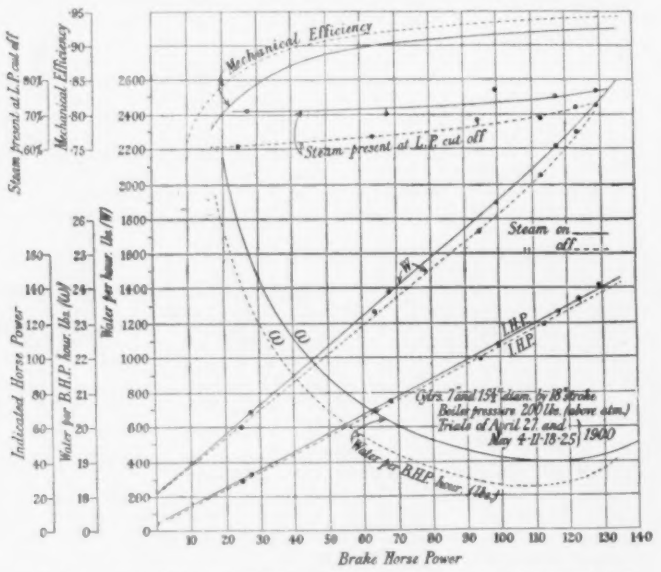


FIG. 2. DIAGRAM PLOTTED FROM TESTS TO DETERMINE INFLUENCE OF REHEATING ON ECONOMY.

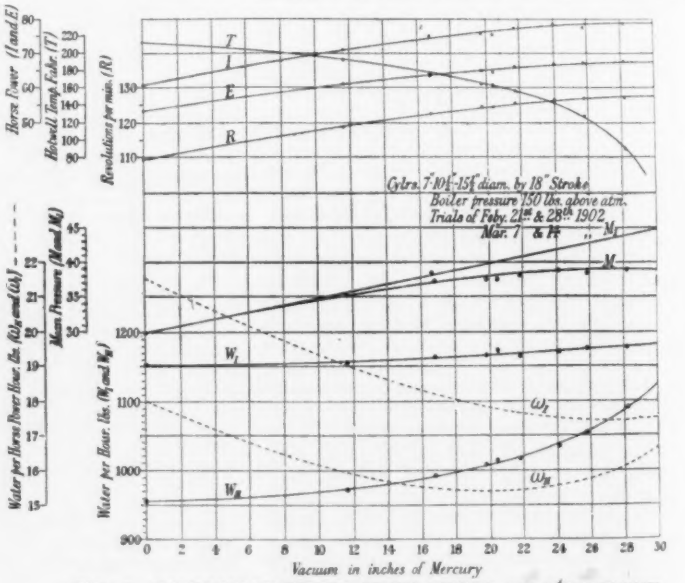


FIG. 3. DIAGRAM PLOTTED FROM TESTS TO DETERMINE INFLUENCE OF HIGH VACUUM ON ECONOMY.

TABLE I.—Results of Trials to Determine Effect of Reheating on Economy.

(Cylinders, 7 and 15½ ins. diameter and 18-in. stroke. Boiler pressure, 200 lbs. by gage. Jacket steam off. Cut-off in low-pressure cylinder, 7 ins. Power varied by shifting high-pressure eccentric. Condensing water adjusted for an approximate vacuum of 24.4 ins.)

No. of Trial	I	II	III	IV	V	VI	VII	VIII	IX	X
Date of Trial. 1900	May 4	May 4	April 27	April 27	May 11	May 11	May 18	May 18	May 25	May 25
Reheater Steam, off or on	off	on	off	on	off	on	off	on	off	on
Shift of H.P. Eccentric, inches	¼	¼	¼	¼	⅜	⅜	¼	¼	⅛	⅛
Pressure in H.P. Steam Chest, lbs. above atm.	195·5	194	197	196	198	197	199	198	198	198
Pressure in Reheater Coils " " "	0	192	0	194	0	194	0	195	0	195
Pressure in Receiver " " "	50	54·3	43	47·5	31	36	16·7	21	1·0	4
Barometer, inches of mercury	29·4	29·4	30	30	29·8	29·8	29·9	29·9	29·75	29·75
Vacuum " " " "	23·12	23	24·4	24·37	24·4	24·3	24·42	24·45	24·2	24·4
Mean Pressure, reduced to L.P. Cylinder, lbs. per sq. inch	58·1	60·4	54	55·6	44	46·5	30·8	32·7	12·36	13·78
Revolutions per minute	133·4	136·1	130·2	134·4	132·8	137·6	133·9	137·5	136·4	143·2
Condensation in Receiver, lbs. per hour	95	49·5	not taken	not taken	81·78	43·96	55·8	32·6	would not drain	would not drain
Condensation in Coils of Reheater, lbs. per hour	0	110	0	106	0	88	0	68	0	22
Total Water used, lbs. per hour, W	2298	2454	2050	2216	1725	1896	1270·6	1378·6	599·5	686
Steam shown by Indicator Cards at L.P. cut off, in percentage of total water	72	76·7	68·4	75	68·3	77·2	60	70	60·4	71
Indicated Horse Power	131	138·8	118·7	126·2	98·7	107·6	69·7	75	28·5	33·3
Brake Horse Power	120·3	126·1	112·6	117·1	94·1	99·5	63·5	67·7	24·3	27·32
Mechanical Efficiency	·918	·908	·948	·928	·953	·925	·911	·902	·854	·820
Pounds Water, per I.H.P. hour	17·54	17·61	17·2	17·5	17·5	17·63	18·23	18·38	21·06	20·59
Pounds Water " B.H.P. "	19·1	19·46	18·2	18·92	18·33	19·06	20	20·36	24·67	25·11

NOTES.—1. Trials were made in pairs—steam off and steam on reheater—the one after the other with a sufficient interval. 2. The brake sluices were adjusted for the first of each pair, and were not altered for the second trial of the pair. 3. In plotting the results on Fig. 2, the powers of Nos. I. and II., are brought up to the average vacuum of the others, viz., 24.4 ins.

given in Table II., and are recorded, after reduction, in Fig. 3. All the results on this diagram are plotted to a base of degree of vacuum. It is therefore necessary they should first be reduced to some constant speed of revolution. The revolutions chosen for this purpose are 120 per minute.

Curve W_1 gives the pounds of water (that is, steam) used per hour (as measured) on this basis.

Curve W_h gives this water expressed in terms of British thermal units expended between the high-pressure steam-chest and the hot-well.

Curves I and E show respectively the indicated horse-power and the brake horse-power, both reduced to the basis of 120 revolutions.

Curve M indicates the mean pressure referred to the low-pressure cylinder as given by the indicator cards.

Curve R shows the variation of revolutions per minute due to variation in vacuum.

If the variation in hot-well temperature be disregarded, curve W_1 gives the steam consumption, and the ordinates of this curve, divided by the corresponding ordinates of curves I and E, will give the pounds of water used per indicated and per brake horse-power per hour, as shown in the curves ω_1 and ω_e. These curves both attain their lowest point at from 26 to 28 ins. of vacuum. Looked at in this way, therefore, the highest vacuum is practically also the most economical vacuum, although it does not appear that there is any gain by going higher than 26 ins. vacuum. This, however, does not give the true economy of the engines, because the feed-water in the case of the lower vacua would carry away from the engines—and presumably to the boilers—a greater quantity of heat per pound than would be the case with the higher vacua. Hence the need for curve W_h, the ordinates of which, divided by those of curve E, result in curve ω_h, which curve represents the true economical performance, namely, heat-units expended per brake horse-power developed, expressed in pounds of water for convenience in comparison. It will be noted that curve ω_h attains its lowest point at or about 20 ins. of vacuum. So far as degree of vacuum affects economy, therefore, it follows that these engines were working with the minimum expenditure of heat units—or, to put it otherwise, coal—per useful horse-power developed, when the vacuum carried amounted to 20 ins.

It is not by any means an uncommon opinion amongst engineers that the highest economy is associated with the highest possible vacuum. This opinion is probably based upon two suppositions, first, that the aggregate mean pressure in the cylinders rises and falls—other things equal—in proportion as the vacuum rises and falls; and, second, that the steam consumption per revolution is—other things equal—not affected by the vacuum. On these suppositions any addition to the vacuum would mean the same addition to the mean pressure, without any addition to the steam consumption. How far the first supposition is from the truth will be seen by comparing curves M and M_1. M_1 is a straight line passing through the point representing mean pressure at zero vacuum, which from the table is seen to be 29.75. The ordinates to M_1 simply are 29.75 + vacuum in pounds per square inch; and this line would represent the mean pressure if the lower condenser temperatures associated with the higher vacua had no condensing effect on the steam acting in the cylinders. Curve M represents the actual mean pressure realized, and the vertical distance between M and M_1 at any vacuum shows the loss due to cooling effect of the condenser at that vacuum. It is seen that the loss grows as the vacuum rises.

How far the second supposition is from the truth is indicated by the upward inclination of curve W_1. This curve virtually represents the water used per revolution at the various vacua, because it represents it at constant revolutions, and the fact that it inclines upwards shows that more steam enters the high-pressure cylinder per stroke at a high vacuum than at a low vacuum. This can only mean that the cooling or condensing effect of the condenser temperature is felt throughout the cylinders even as far as the high-pressure admission. Had the vacuum no effect upon the weight of steam admitted per stroke into the high-pressure cylinder, curve W_1 would simply be a horizontal straight line.

The indicator cards, as well as the recorded receiver pressures, show this fact in another way. Specimen indicator cards are given in Fig. 4, from which it will be seen how the high-pressure exhaust "sympathizes" with that of the low-pressure, and how the steam line, as well as the exhaust line, of the intermediate cards follow suit. In connection with all this, it is to be borne in mind that no adjustment or condition about the engines was altered during the trials, with the single exception of the amount of condensing water. All the variation in results must therefore be due to this single cause. Mechanical efficiency does not appear to be materially affected by degree of vacuum. Partly for this reason, and partly in order to avoid confusion in the diagram, the curve of water used per I. H-P. in terms of W_h has not been drawn. It is to all intents and purposes parallel with that for B. H-P., but occupying a lower position on the diagram.

These experiments have been made on triple-expansion engines. The question naturally arises, would similar results follow from experiments on double and quadruple expansion? A thoroughly conclusive answer can only be obtained by direct tests, and such will probably be carried out later on, with these engines. Certain predictions from the foregoing results may, however, be fairly hazarded. The fewer the number of cylinders intervening between the steam pipe and the condenser, the greater would be the general effect of the condenser temperature upon the working steam in the cylinders; and, vice versa, the greater the number of cylinders, the less would be the condenser effect upon this steam. It may therefore be expected that in a two-cylinder compound engine the vacuum associated with maximum economy will be somewhat less than 20 ins., while in the case of a four-cylinder quadruple-expansion engine the corresponding vacuum will be somewhat higher than 20 ins. During the whole of these trials steam was shut off from the cylinder jackets. How far the results may be modified—if at all—by the use of jackets will be subject of future tests.

TABLE II.—Results of Trials to Determine Effect of Varying Vacuum on Economy.

(Cylinders, *I*, 10½ and 15½-in. diameter, and 18-in. stroke. Jacket steam off. Receivers drained continuously. Cut-off in each cylinder 10½ ins. Brake sluices shut 1-in.)

No. of Trial	I	II	III	IV	V	VI	VII	VIII	IX
Date of Trial. 1902	Mar. 14	Feb. 28	Feb. 28	Feb. 28	Mar. 7	Feb. 21	Feb. 21	Feb. 21	Feb. 21
Vacuum—inches of mercury	0	11·53	16·70	19·69	20·40	21·79	24·07	25·72	28·18
Condensing Water / Feed Water	—	5·7	7·0	8·4	8·3	8·7	11·2	15·3	43·7
Barometer	29·7	29·15	29·15	29·15	29·7	29·85	29·85	29·85	29·85
Pressure in H.P. Steam Chest (above atm.)	147	146	147	148	147	151	150	148	149
Revolutions per minute. (R)	109	118·6	122·6	124·5	124·3	125·4	126·6	127	127
Indicated Horse Power	54·7	70·2	78·9	78·7	78·5	81	83	82·2	82·4
Brake Horse Power	48·3	60·3	64·9	67·4	66·9	69·1	70·6	71·1	71·5
Mechanical Efficiency	·882	·859	·844	·856	·852	·853	·850	865	·857
Total Water used per hour in pounds. (W)	1048	1141·5	1189·5	1210	1218	1217	1235	1246	1247
Hotwell Temperature °Fahr. (t_2)	212	193	177	164·5	164·3	157	142·8	129·2	88·8
Mean Pressure reduced to Low-pressure Cylinder (M)	29·75	35·06	37·13	37·41	37·33	38·22	38·85	38·32	38·85
I.H.P. at 120 Revolutions. (I)	60·3	71	75·2	75·8	75·7	77·5	78·7	77·6	78·8
B.H.P. at 120 Revolutions. (E)	53·2	61	63·5	65	64·6	66·1	67	67·2	67·6
Water per Hour at 120 Revolutions. $(W_1) = \frac{120\,W}{R}$	1154	1155	1164	1166	1175	1164	1170	1177	1178
Heat Units per Hour at 120 Revolutions* $(W_h) = \frac{W_1 (T_1 - t_2)}{T_1}$	934	973	996	1003	1016	1015	1033	1053	1092

*T_1 = total heat—above zero F.—per lb. of steam of boiler pressure. (W_h) = heat units reduced to lbs. of water for comparison.

A UBIQUITOUS GARBAGE DISPOSAL COMPANY is proposing to solve the garbage problem of American cities with little or no cost to cities or citizens and presumably with great profit to its stockholders. At least such is the inference to be drawn from the fact that from July 22 to 31, inclusive, newspapers at Lawrence, Lowell, Springfield and Worcester, Mass., and at Harrisburg and Reading, Pa., all published articles with display headlines telling how the United States Garbage Reduction Co., of Lynn, Mass., proposed to install the Day system of garbage disposal in the respective cities, if given the chance. In the Harrisburg "Patriot" for July 24 it is claimed for the process that everything included under the heads "garbage, including ashes and offal," is utilized except "the water contained in the garbage," and even the water is not allowed to leave the works until it has been "collected by a molecular gravitator and distilled as a sanitary precaution." Of the garbage proper, the same paper states, 20% "is changed into fertilizer and commands a good price as such." Coal is reclaimed from ashes "and the resultant can be sold at 75 cts. a ton," while the "residue of the ashes is used in the manufacture of fire brick." Sheet iron and solder from tin cans are reclaimed and sold. In short, the company is represented as claiming that $8 can be realized from every ton of garbage collected. The various accounts indicate that exclusive franchises for collection and disposal are sought, although the reception of material collected by the city would be gladly considered. In case the company collected the garbage, a Reading paper stated, 20 tickets would be issued for a dollar, each ticket entitling the holder to receive one clean, disinfected can in place of one filled with garbage. By removing the cans without emptying them on the street "the contents of the can would not be shaken up, and thus the spread of disease germs would be avoided."

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ADVERTISING RATES: 20 cents a line. "Want" and "For Sale" notices, special rates, see page XXIV-XXIX. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.

The movement for the adoption of a standard size of trade catalogues can perhaps be hardly called a movement, as its progress is so very slow. Nevertheless, we believe that some advance is being made toward uniformity, and that the proportion of 6 × 9-in. catalogues is increasing year by year. The surprising thing about the whole matter is that manufacturers and dealers in engineering supplies should be so blind to their own interests. When a firm has invested thousands of dollars, more or less, in publishing a catalogue, it is manifestly for its interest to have that catalogue made use of by its customers and not thrown away or stowed in some obscure corner where it will be forgotten. Yet when such a firm permits the manager of its publication department or its printer, or whoever has charge of the matter, to make a catalogue of some odd size, perhaps too high to stand on an ordinary shelf or of greater width than height, so that it refuses to go with others in a proper classification—when it commits such a piece of folly, it is deliberately consigning a large percentage of these expensive catalogues to the waste-basket or to the top shelf where they will be forgotten.

We wish the publication manager of every firm dealing in engineering supplies could have indelibly impressed on his mind the fact that there are several thousand engineers and business firms in this country who are large purchasers of supplies, and who systematically file for reference every good trade catalogue in their line which they receive, provided, of course, that it contains matter worth referring to, and provided also that they have a place to put it. If a catalogue is 6 × 9 ins. there is always room for it. If it is one of the odd sizes that refuse to associate with any other books or pamphlets, it may find a place or it may not, but in either case it cannot be classified in its proper place in the catalogue file, and will very likely be missing when the time comes that something is to be bought in that particular line.

If there is any reason why at least 99 catalogues in every 100 could not be made exactly 6 × 9 ins. we have yet to hear it offered.

A notable example of co-operation among engineering societies is the "John Fritz Medal," which is to be awarded each year to the originator of the most useful industrial or scientific achievement, the award to be made by a committee of 16, made up of four members from each of the four national engineering societies. The award is to be made annually, but the subject of the award must be given at least a year of consideration, a very proper requirement, since the relative values of the different inventions or discoveries of a given year can be much more accurately determined after the developments of a year or more following.

The establishment of this medal is due to a number of prominent engineers who have taken this method to appropriately celebrate the eightieth birthday of John Fritz, which will occur on October 31. On that date a dinner will be held in New York city in honor of Mr. Fritz. Inasmuch as Mr. Fritz's work has been noteworthy in many departments of engineering, it is appropriate that all the societies should share in controlling the award of the medal.

Does reheating steam between the cylinders of a compound engine pay? An English engineering professor has been experimenting on this matter and has come to the conclusion that it does not. We print in another column of this issue the paper read by this gentleman at the recent meeting of the Institution of Mechanical Engineers in which these experiments are described in detail. We also find in our English contemporary, "The Surveyor," a report of the informal speech with which the author prefaced his paper, and as it is particularly interesting to American readers, we reprint it as follows:

> Professor Weighton told how he was led to commence these investigations. In Milwaukee he had a chat with a gentleman who was said to be the greatest steam engine expert in America, and he asked this gentleman what benefit was derived from the employment of reheaters. The expert looked curiously at his English visitor, and said that everybody asked him the same question; he added that he did not know what benefit was derived, but reheaters were the fashion, and they were accordingly put in.
>
> When Professor Weighton returned he determined to test the Yankee "fashion" for himself, and accordingly experiments were conducted under his guidance at the Durham College of Science. The result, Professor Weighton told his hearers, was that there was "nothing in the Yankee plan, and worse than nothing in it," for instead of being an advantage the reheater plan was a positive disadvantage. It lowered the mechanical efficiency of the engine, and increased the steam consumption per horse-power developed. The consumption per brake horse-power was in all cases consistently greater when the heater was in use, the average increase being 2.6% against the heater, whilst in terms of water per indicated horse-power the results were 0.18% against the heater.

If this report of Prof. Weighton's remarks is authentic, his British hearers must have been immensely entertained. A pretty kind of showing American mechanical engineering makes when you investigate it! Corner the "greatest steam engine expert in America," and he has to candidly admit that he designs his engines by the rulings of fashion and not of science. The reheating receiver on our engines stands by this token in the same category with the Panama hat and green veiling!

How do we explain it? We can't attempt to explain it. We can only suggest that if Prof. Weighton had pursued his investigations further and become able to understand an American joke, he might have departed for his native island a wiser man.

To what extent the steam reheater makes for economy or against it, we shall not attempt to discuss at length. We will merely point out that it amounts really to superheating on a small scale, and on a plan which is free from the troubles and difficulties which attend superheating to a high degree. There is good reason to believe that it accomplishes everything for economy that a steam jacket on the low-pressure cylinder accomplishes with a good deal less cost and complication. Aside from the matter of economy, it effects a notable increase in the capacity of an engine, as Prof. Weighton's own tests show, and it probably reduces very considerably the risk of accident from water in the low-pressure cylinder.

Since the above was in type some of our English contemporaries have come to hand with reports of the discussion upon Prof. Weighton's paper. For the most part the remarks are far from illuminating as to the real reason why the tests showed such poor results from the reheater. "Engineering," however, suggests that possibly the Professor failed to place an independent lubricator on the low-pressure cylinder. If this were the case the reheater receiver would act as a trap and catch the lubricant leaving the high-pressure cylinder, thus causing the low-pressure cylinder to run with considerable extra friction when the reheater was in use.

A noteworthy illustration of the extent to which instruction by correspondence is receiving recognition is furnished in the announcement of one of the leading correspondence schools that it has completed arrangements for co-operation with a technological institute. The schools referred to are the American School of Correspondence of Boston, and the Armour Institute of Technology of Chicago. Under the arrangement made, the teaching staff of the Armour Institute "will constitute a board of instruction, revision and examination for the American School," according to an announcement by Dr. Gunsaulus, the President of the Institute. Work done by correspondence students which conforms to the standards fixed by the Armour professors, will be accepted and credited at Armour Institute when correspondence students desire to continue their work by actual residence there. Under this arrangement, the American School is to remove its headquarters from Boston to Chicago, where it will be located at the Armour Institute.

There has been, as many of our readers will recall, some pretty severe criticism of correspondence school methods, much of which has doubtless been deserved. At the same time, broad-minded educators all agree that the correspondence schools, although conducted purely as money-making enterprises, have revealed a demand for educational advantages which no one dreamed of before, and which from every point of view deserves to the fullest degree the recognition and aid of educators and philanthropists. No more beneficial use could be made of the Armour Institute endowment, we believe, than to aid in perfecting and developing the work of instruction by correspondence.

The first attempt to bring Greene and Gaynor back from Canada to the United States has failed; but we trust the Department of Justice will try again. Since it took nearly two years merely to secure an order from our own courts for the removal of these men from one judicial district of the United States to another, it is not remarkable that able lawyers should be able to delay through technicalities their extradition from a foreign country. Meanwhile, it is worth inquiry why steps are not taken to collect the bail bonds which were forfeited when Greene and Gaynor fled to Canada. So much of their ill-won wealth, at least, ought to be returned to the U. S. Treasury; and it would serve to pay a part of the expense to which the Government has been put in endeavoring to secure their extradition.

Whether they are ever brought back to the United States and convicted or not, it is worth while pointing out that they are already suffering punishment of a sort that to any right-thinking and rightly constituted man must be far worse than any penalty within the power of a court to inflict. What could be worse to a man with the least spark of manhood than to have his name branded throughout a nation as a criminal and held up for universal contempt. Curiously enough, it is just this punishment which Greene and Gaynor brought upon themselves by their flight to Canada. Prior to that time there had been com-

paratively little heard by the public for some years of the efforts being made to bring these men to justice. The average newspaper reader, we presume, had quite forgotten who Greene and Gaynor were. Their flight to Canada, however, and the events following, brought their crime to the notice of millions who had never heard of it before, and made it impossible for them ever to again live in any English-speaking community with even a vestige of respect. The story of their crime has been retold in thousands of newspapers in all parts of the country, and their flight has been universally accepted as complete assurance—if assurance were needed—of their guilt.

Can wealth, or anything that wealth can bring, buy any real pleasure for men who gain it on such terms? Flight to a foreign land and refuge there among criminals may save the outward punishment; but the real and deepest punishment is being inflicted daily and no technicality of the law can save them from it.

We call attention to these facts, because there is an unthinking tendency to consider that Greene and Gaynor have won in escaping thus far the clutches of the law. What we want to point out is that no victory is possible for them, and their present punishment should be as effectual a deterrent to those tempted in a similar way as if these men were now confined at hard labor in a penitentiary. Yet at the same time, this is no reason why the effort to bring them to the bar of justice should be relaxed. On the contrary, such efforts should be redoubled. There is particular need at the present time of an object lesson to show that the criminal law bears equally on the rich and influential and on the poor and friendless, and this will be afforded if final success is attained in bringing these wealthy contractors to justice.

THE PROGRESS OF BLOCK SIGNALING ON AMERICAN RAILWAYS.

Fifteen years ago, American railways, taken as a whole, may be said to have been in the dark ages, so far as signaling systems for the movement of trains were concerned. With the exception of a very few progressive companies, such as the Pennsylvania, railways everywhere were moving their trains, both on the open road and in yards, by the old-time methods inherited from the early days of railroading. To this statement one qualification should be made, however. The first system of moving trains used was the "time-table" system, under which conductors and engineers were to a large extent a law unto themselves. This was superseded by the telegraphic train order system, under which responsibility was concentrated in the train dispatcher, and fifteen or twenty years ago it was hard to find a railway officer who thought that anything better was needed. Gradually, however, the fact came to be appreciated that on a large proportion of American railway mileage the traffic had grown to a density which demanded better and safer means for its movement. Just as English railways at an earlier date had been forced to revolutionize their system of train movement in order to carry their growing traffic with a reasonable degree of safety, the railways of this country found themselves compelled to take a similar course.

There lies before us a very complete exposition of the present status of railway signaling in the United States. It is in the form of a report of the Committee on Safety Appliances of the American Railway Association, and it covers no less than 135 pages of the official report of the Association's meeting at New York in April last.*

The report opens with some interesting statistical summaries, from which a very good idea of the progress in signaling during the past dozen years can be gained. It shows that at the date of the report (March 20, 1902) 25,000 miles of railway in round numbers in this country was protected by block signals. Taking the total mileage of the country at 200,000 miles, it will be seen that about one-eighth of our railway mileage is covered by block signals. This, however, gives an inadequate idea of the importance which the block signal has attained. The track protected by block signals is made up for the most part of lines on which a very heavy traffic is moved. This is indicated, for example, by the fact that 7,640 miles out of the total covered by block signals have double, triple or quadruple tracks. It will be manifest that a single mile of a four-track trunk line, like the Pennsylvania or the New York Central, represents as much traffic movement as twenty, or perhaps fifty, miles of a railway located in an out of the way district handling only a light local traffic. Taking these things into account, it is a fair estimate that from one-fourth to one-third of American railway traffic is now moved under protection of block signals.* Compared with the condition of affairs fifteen years ago, this is distinctly encouraging.

In considering the significance of these figures, it should next be noted that the block system means very much more on some railways than on others. While even the simplest form of the block system—the mere adoption of a space-interval system instead of a time-interval system to keep trains apart—is a great advance over the older practice; it is also true that the 25,000 miles which the block system covers represents wide extremes of practice. This variation is partially covered in the statistics before us by division of block signal systems into three classes, viz.: telegraphic block, controlled manual block, and automatic block systems. The telegraphic block amounts on some roads to little more than mounting semaphores at stations and giving to station-masters the additional work of signalmen. The term applies in general, however, to any block system in which the signals are operated by hand according to instructions received by telegraph. In the "controlled manual system" additional mechanical and electrical safeguards are introduced to prevent a clear signal being given when a train is in the block ahead. The automatic system, as is well known, is operated by the trains themselves. No separate summaries of these various types classes of block signal are given in the report before us; but taking the returns made by the separate companies we have added them and obtain the following total miles of track equipped with each system:

Telegraph block	23,100 miles
Automatic block	4,815 "
Controlled manual block	2,321 "

These figures give a better idea of the relative use of these systems than if we had used miles of road instead of miles of track. For example, by far the most extensive example of the controlled manual system is the four-track main line of the New York Central & Hudson River R. R., from New York to Buffalo, and this accounts for 1,492 miles of the entire controlled manual equipment. The next largest user of the system is the New York, New Haven & Hartford, which has 471 miles of track equipped with it. The only other two roads having more than a few miles so equipped are the Erie and the Chesapeake & Ohio, each of which reports over a hundred miles.

The largest users of automatic block systems are the Lehigh Valley and the Reading, the former reporting 602 miles in operation and the latter 731 miles. The Pennsylvania also reports 665 miles as automatic; but this doubtless refers to the electro-pneumatic system, which is much more elaborate and expensive than the electric system which is usually referred to when automatic signals are reported, and so far as these features are concerned the Pennsylvania automatic equipment should be ranked with the controlled manual systems.

Similar analysis of the reports as to the telegraph block would be to some extent misleading, as the term covers so large a variety of practice. The Southern Ry. reports the largest mileage of tracks covered by this system—4,728 miles; but we believe in this case only passenger trains are governed by it.

The Pennsylvania lines west of Pittsburg report 3,176 miles equipped with telegraph block, while 2,070 miles are so equipped on the lines east of Pittsburg. Other large users of the telegraph block are the Chicago, Milwaukee & St. Paul, with 2,677 miles; the Chicago & Northwestern, with 1,787 miles, and the Lake Shore & Michigan Southern, with 1,939 miles. It is of some interest to note that the automatic system is reported in use on a larger number of roads than the telegraphic system, the total number being 37 in one case and 35 in the other.

The extent to which the distant signal is—or is not—in use, can be judged from the statistics furnished as to the total number of each class of signals as follows: 13,836 home signals and 4,428 distant signals. In general, the distant signal is little used with the simpler forms of telegraph block, but is very generally used with the more elaborate systems of blocking.

Besides the statistical inquiries, the report gives considerable matter of interest relating to the practice of the different roads in the operation of their systems. Question 6 in the committee's circular of inquiry was as to whether a separate signal was used for train orders, where the block system is used. To this question 27 roads answered yes and 19 roads answered no. With automatic block systems a separate train order signal is, of course, a necessity, but with telegraph blocking it is quite common to use the block signal to notify a train to stop for orders.

In operating a single-track railway, the simplest application of a block system is to keep trains which are following each other spaced a proper distance apart, leaving to the dispatcher the responsibility of protecting trains against butting collisions. Twenty-three single-track roads reporting to the committee, however, replied that they used the block to protect trains in both directions, and 13 other roads reported that opposing train movements were provided for on part of their mileage equipped with blocks. Only six roads using the block system on single track reported that opposing train movements were not provided for.

In the mounting of signals, a separate mast is usually provided for each track in the case of the automatic or controlled manual systems; but with the telegraph block system a large number of companies use the same mast for semaphores governing movements in opposite directions. Others, however, erect separate masts, even on single-track lines, and for double-track lines this plan is generally favored.

Practice also varies widely as to the number of semaphore arms permitted on a single mast. As summarized in the report, 9 roads allow but one signal on a home mast, 25 roads have two signals, 11 roads permit three and 2 roads permit four. On the distant signal mast, 28 roads have but one signal and 7 roads permitted two signals. The answers to this question, however, were somewhat confused by the common practice with automatic systems of placing the distant signal for one block on the home signal mast of the preceding block.

On the much-discussed question of white or green lights as a safety signal at night, practice still favors the white light, but opinion has turned in favor of the green, and a large majority of the replies to the committee's circular (36 to 9) approve the green light as the best. It will doubtless be only a question of time when green will be generally adopted as the standard color for safety in railway signaling.

To the question, what color should be used for caution if green is adopted for safety, 24 roads favored yellow and 7 roads favored the combination of red and green, such as is used on the Chicago & Northwestern R. R.

In conclusion, it may be said that the progress toward uniformity in practice is very encouraging, and nothing can aid more toward such uniformity than such full records of the variations in practice as the American Railway Association has collected.

The greatest need at the present time is extension of the space-interval system to protect trains on a much greater mileage and the education and discipline of employees engaged in train service—and not a few officials as well—to a better appreciation and use of the systems already installed. It must be frankly said that collisions under the block system are far from unknown; but the fault is to be laid, not at the door of the system, but to its misuse or lack of use. English

*Copies of this report (price $2) may be obtained from the Secretary of the Association, Mr. W. F. Allen, 24 Park Place, New York city.

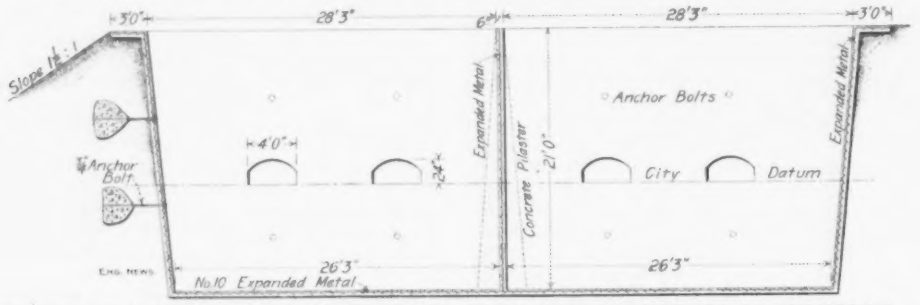
*Perhaps some modification of this estimate should be made as respects freight traffic, for on a considerable percentage of the roads equipped with block signals, freight trains are not governed by them.

experience under the rigid Board of Trade rules has proved that it is possible by proper use of the block system to almost entirely prevent accidents from collisions.

LETTERS TO THE EDITOR.

A Novel Method of Anchoring a Concrete Steel Lining for a Septic Tank.

Sir: In connection with the descriptions of concrete-steel retaining walls in your issue of Aug. 7, the enclosed print of a septic tank I designed for the city of Santiago de Cuba may be of interest to you. The tank was to be excavated in a bank of exceedingly stiff clay, and as it would constantly remain full, no great strength would be required in the walls. The anchors are, I think, something rather new, and might be applied to walls requiring greater strength. The design was verbally accepted, but too late for action by military government.



SECTION OF CONCRETE-STEEL-LINED SEPTIC TANK, SHOWING METHOD OF ANCHORING LINING.

Respectfully, W. H. Clay,
Late Office Engineer, U. S. Engineer Office, Santiago de Cuba.

Cost of Relaying Brick Pavements.

Sir: I agree with Prof. Baker (Eng. News, Aug. 7) as to the number of paving brick an experienced man will lay; and while this subject is being discussed, I would like to know the difference in cost in cleaning brick where a tar filler has been used in different seasons of the year. I have found that cleaning brick with tar filler in hot weather is rather expensive, costing more than twice as much as the figures given by Mr. Gillette, and those taken from Engineering News of May 5, 1898.

This work of taking up and relaying pavements is being extensively done by interurban railway companies to accommodate the heavy cars and traffic that the roadbed and track are required to stand, as the ordinary track built for city cars but a few years ago is entirely too light for interurban cars, thus necessitating a new track and roadbed.

A discussion of the cost of taking up and replacing pavements would certainly be of value, both to railway engineers and city officials engaged in such work.

Yours truly, T. E. Petrie.
Marion, Ind., Aug. 11, 1902.

(We shall be pleased to hear from any of our readers who can contribute detailed figures as to the cost of such work.—Ed.)

Cost of Laying Brick Pavements.

Sir: I desire to add a few remarks to those offered in Engineering News of Aug. 7 by Prof. Ira O. Baker regarding the cost of brick pavement as given by me in Engineering News of July 24. I there gave 7,500 brick laid by a paver as a fair ten-hour day's work, while Prof. Baker has "incontestable evidence" that 15,000 is nearer a fair average. I should give much greater weight to this statement of Prof. Baker's had he said that he had actually seen such an average maintained day in and day out than that he has "evidence" to that effect.

To begin with, I am well aware that a skilled paver can lay 15,000 brick in ten hours, but in estimating one should base his figures, not upon what can be done, but what actually is done ordinarily where labor unions exist. Nor is it fair to cite a case where in five hours more than 15,000 brick have been laid. Short time tests are always deceptive. Indeed, a test extending over one or two days is not always to be relied upon, especially the first few days or the last few days of a long job. One must have data based upon long time observations to be of much value; nor should one take the word of men who have done work at an exceptionally rapid rate and consequently like to brag of their achievement; nor can one base an estimate upon records of "stint work," or where workmen are paid by the piece or per square yard of work done per day. As for short time observations, an example will suffice. I saw a laborer load 1 cu. yd. of sand (loose measure) into a cart in the incredible short time of five minutes, but shall scarcely base my estimates of cost in future thereon. It is not impossible that in Illinois, where brick pavements are more frequently laid than farther East or farther West, men have greater skill in brick laying; and, as above suggested, labor unions there may not have caused as yet a restricted output of work, as they often do.

I note that the one example of speed in brick laying, extending over many days, quoted by Prof. Baker, agrees very closely with my own experience. He quotes the cost of laying brick pavement in Minneapolis as having been 3.2 cts. a cu. yd. Turning to the itemized cost given by me, and omitting the items of spreading sand, grouting, raising sunken brick, and foreman, which were not included in the Minneapolis example, we find a cost of 3.2 cts. also; and the wages were practically the same. It seems apparent that the Minneapolis pavers were about as rapid as those whose work I gave as an average.

In closing, I would like here to express appreciation of the value of the traction tests by Prof. Baker, published in your issue of March 6. To many it may have been surprising to see so low a tractive resistance on brick and macadam, but a study of traction data and theory had previously convinced the writer that the nature of the material of the surface coat of a pavement has less effect upon resistance than would seem at first sight; and now it appears that the best stone block, brick, asphalt, macadam and plank pavements each show a resistance of about 20 lbs. per ton. Upon a comparatively smooth, clean surface the resistance is due to the wave-like depression of the surface under the wheel load. The thicker the pavement and the more rigid and beam-like in its behavior in distributing the load over the subsoil, the less it will bend and the less will be rolling friction. In view of this consideration, I think it not at all likely that any brick pavement, however smooth its surface, will show a tractive resistance as low as 8½ lbs. per ton with an ordinary wagon (the possibility of which is suggested by Prof. Baker), unless the concrete foundation be given a thickness considerably in excess of 6 ins. and the "sand cushion" be reduced to a minimum. A "sand cushion" 2 ins. thick for brick is altogether excessive. Such a thickness for stone blocks is necessary to equalize inequalities of size, but for brick a "sand cushion" should be no thicker than is necessary to take up irregularities in the concrete surface, say ¾-in.; for the thicker the sand the greater the subsequent irregularities that will develop and the greater the resistance to rolling friction, even where the surface remains smooth. I fully agree, therefore, with Prof. Baker in believing that care and judgment in the use of the "sand cushion" will effect a decided reduction in tractive resistance.

Yours truly, Halbert P. Gillette.
Rochester, N. Y., Aug. 13, 1902.

The Superiority of Hand Molded Over Machine Molded Briquettes in Testing Cement.

Sir: Mr. Thomas S. Clark, in his excellent article in Engineering News of July 24, refers briefly to the superiority of hand molded over machine molded cement briquettes.

Several years ago the writer was called upon by a large cement importing firm to make a series of tests of Portland cement. Some 40,000 barrels of a well-known and excellent brand, furnished by this firm for an important piece of Government work, had been rejected by the engineers as failing in requirements, particularly in regard to tensile strength. As the engineers were men of well-known ability and honesty, and the brand had previously given only the best results under rigid specifications, the result was both surprising and perplexing.

The department very kindly placed at my disposal the testing apparatus in the Government laboratory, where previous tests had been made. This consisted of a large Riehle testing machine, the usual conveniences for mixing, immersing vats, heating apparatus and a hydrostatic molding machine. In operating this molding machine, the forms were first filled with cement mixed by hand, which was then subjected to a pressure of about 1,500 lbs. on the briquette by a plunger operated by water pressure.

When taken out of the machine immediately after forming, and forms being unclamped, the briquettes could be handled freely without breaking; in fact, an appreciable effort was necessary to produce rupture. All briquettes for test, however, were handled with precisely the same care as in case of hand molded specimens. As all fractured specimens showed compact and uniform structure, a favorable outcome appeared encouraging, and I was scarcely prepared for the results, which were below the standards claimed by the manufacturers and their agents and very little in excess of the results secured by the Government engineers.

As previous tests of the same brand of cement used on other work with which I had been connected had shown better results from hand molded specimens, I concluded to try this method, although not without some misgivings as to results. Briquettes were mixed identically the same way from the same sample sack of cement and with the same percentage of water, etc., the only difference being that the cement was compressed in the molds by the thumbs instead of by hydrostatic pressure. The average results of a large number of tests were as follows:

How mixed.	Per cent. of water.	Tensile strength, in lbs. per sq. in. 1 day.	7 days.	28 days.
By hand	20	73	483	553
By machine	20	70	468	550

The table is self-explanatory. As in Mr. Clark's experiments, the difference was not reached until the 28th day. As a result of these investigations, I was subsequently informed by the agents that the cement in question had been accepted, as the 7 and 28-day tests of the hand molded briquettes exceeded Government requirements.

Respectfully, A. A. Riffle.
204 Front St., San Francisco, Cal.,
Aug. 7, 1902.

(Interested readers are referred also to our issues of March 5 and April 2, 1896.—Ed.)

Notes and Queries.

"T. C. B.," Washington, D. C., asks the number of miles of electric and steam railway tracks in the United States. The last report of the Interstate Commerce Commission gives the total miles of track as 258,784. The miles of railway were 193,346. The above is all, with unimportant exceptions, steam railway mileage. No equally accurate statistics of electric railways are available, but 20,000 miles is probably a fair estimate of their present extent. "T. C. B." also asks the number of cross ties in use, and the number annually used for renewal. The number per mile of track varies considerably, but 2,500 per mile would be a fair average. The life is from 4 to 12 years. In a report to the Forestry Division of the Department of Agriculture, in 1895, the annual consumption of railway ties in the United States was estimated at 90,000,000. It is doubtless much above that at the present time.

THE STOREY VARIABLE-SPEED ELECTRIC MOTOR.

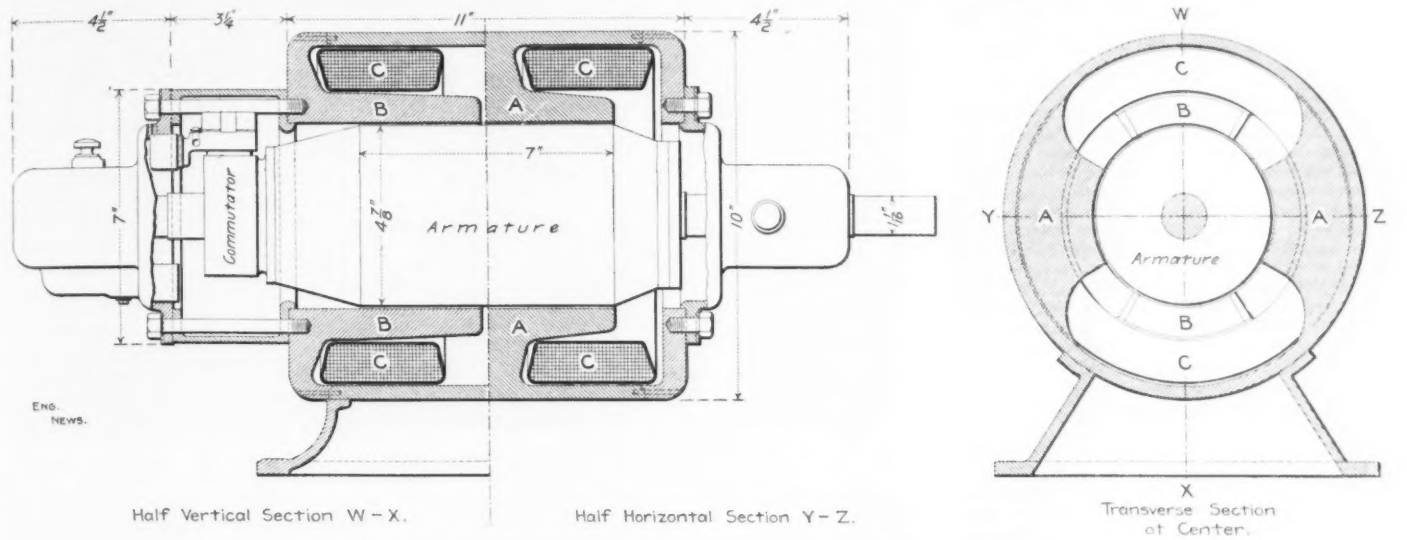
The application of electricity to the direct driving of machines in shops and factories has long been regarded as a promising field for development, equally so by mechanical and electrical engineers. In the exploitation of this field much progress has been made, but what has been accomplished is far less than was at first confidently expected and predicted. This has been due mainly to one thing: the lack of an electric motor which, besides being economical and reliable, could adapt itself to a wide range of conditions of speed and load. Electricians have fully realized this want and many attempts have been made to meet the deficiency, but without complete success.

One effort in this direction, as an example, is represented by the well-known multiple-voltage system, which has been applied to a large number of installations. This system solves the problem indirectly, by using an ordinary shunt motor and supplying it with a number of different voltages from a system of multiple supply-circuits. The different voltages enable the motor to run at correspondingly different speeds, with full reliability and economy. Another way of dealing with the difficulty was illustrated in these columns but a short time ago. Here the desired result is obtained with a single supply circuit feeding a motor of special design (Eng. News, May 1, 1902). This motor has field-poles provided with cores arranged to be moved toward or from the armature. By this means the strength of field can be varied, and the normal speed of the motor changed correspondingly.

A new motor has just been put upon the market which aims to accomplish the same object more completely and in a simpler manner. It is manufactured by the Storey Motor & Electric Co., of Harrison, N. J., and is the invention of Mr. Imle E. Storey, President of the company. The motor

possesses a remarkable speed-range, and operates throughout this range equally economically and with equal ability to adapt itself to changes of load. The motor is electrically an ordinary shunt motor, and possesses all the properties of such machines; its magnetic field, however, is of peculiar form, and this is the novel feature of the machine.

The essential parts of the Storey motor are shown in the drawing, Fig. 1, from which its construction will be understood. The armature is shown only in outline, and is in every way the same as such armatures are usually constructed.



Half Vertical Section W – X. Half Horizontal Section Y – Z. Transverse Section at Center.

FIG. 1. SECTIONAL ELEVATIONS OF STOREY VARIABLE-SPEED MOTOR.

The field, however, differs from accepted forms both in the disposition of its iron and in the shape and arrangement of its winding. The frame of the field is a cast-iron cylinder, which constitutes also the enclosing case for the machine. In the middle of its length it bears internally two diametrically opposite pole-pieces, A A in the figure, which have long pole-tips connected to the case by short stems. Other poles, B B, intermediate between these, project from either end of the case toward the middle, being connected at their outer ends to ring-shaped castings which close the case at its ends. These ring-castings also carry the armature shaft bearings. At one end the bearing forms part of the end ring; at the other it is part of a separate casting which is bonnet-shaped to make room for the commutator.

The machine has thus six field-poles. The two central poles A A are all of one polarity, the poles B B are all of the other magnetic polarity. The field winding is in two coils, C C, one toward either end of the case; the coils are concentric with the armature and occupy the annular spaces between the outer case and the projecting pole tips. From its shape this winding has been given the name "solenoid winding." The normal direction of the field produced by the coils would be parallel to their axis, directed from the two ends of the armature toward the middle. This field is, however, greatly modified by the peculiar distribution of the iron in the field; the lines of force are directed along the poles B B, across the air-gap down into the armature, pass along the armature laminations at right angles to the magnetization and thence pass up across the air-gap into one of the poles A A.

It seems probable that in this way there is produced a considerable concentration of the magnetic flux along the edges of the pole-pieces, and that changes in the field excitation affect mainly the density of the flux on the interior of the pole-faces. This gives a very "stiff" field, i. e., a field that is little distorted by the armature reaction and hence is little influenced by variations in the relative strength of the armature current. This means that the speed as well as the load of the motor can be varied over a wide range without affecting the action at the commutator of the motor.

On actual trial the motor is found to possess to a marked degree this ability to run at widely differing speeds. It will easily give a variation of speed up to 300 to 400% above normal. A rheostat is arranged in the field circuit, and by it the strength of the field can be varied. With a shunt motor, as is well known, the speed increases when the field is weakened and decreases when the field increases in strength, other conditions remaining the same. With ordinary shunt motors any considerable change in speed causes bad sparking at the commutator, but as was brought out above the Storey motor gives no trouble in this way. Thus, when the motor is once started the speed is at all times under control through the field rheostat; simply shifting the handle of the latter at once changes the speed of the motor as may be desired.

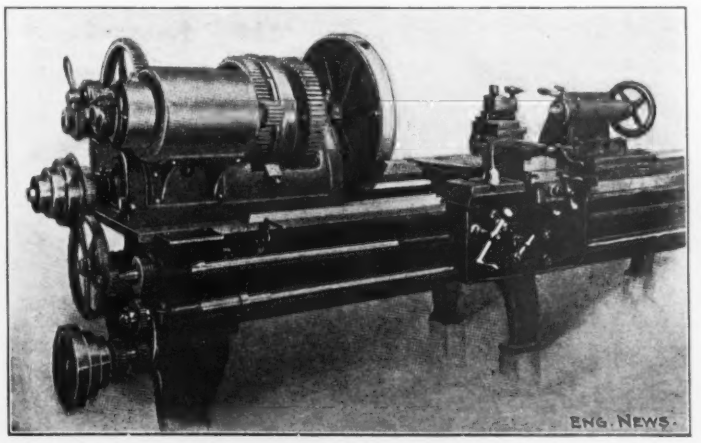


FIG. 2. VIEW OF LATHE FITTED WITH STOREY MOTOR.

The value of such a simple arrangement of a motor for driving machines and machine tools is readily appreciated. The motor, its starting box, and the speed-changing rheostat, are all mounted on the machine in any convenient manner; the speed can be set at any point, or changed instantaneously to suit the work, without pulleys, belts, speed-changing gears, or similar devices. The machines and tools in the shop of the Storey Motor & Electric Co. are all motor-driven in the manner described. The fact that the motors are entirely enclosed and thus protected from dirt, oil and mechanical injury makes them particularly suited for work under such conditions. The simple speed-changing arrangement is especially convenient in case of lathes, for instance; while at work on one piece, the lathe may be at any moment changed in speed to suit varying diameters of the piece, different tools and depths of cut, etc.

Enclosed motors, due to their small radiating capacity, are very apt to give trouble from heating under continuous operation even when worked entirely within their capacity. The Storey motor is claimed to give very good results as to temperature rise. The motors applied to various tools in the company's shop, at our representative's visit were running quite cool, though operating all day and apparently none too large for their work. In mechanical construction and general excellence the makers claim this motor to be fully the equal of any similar machine on the market.

The Storey motor is not a new invention, strictly speaking. The form of construction was patented almost a decade ago by Mr. Storey, as a motor that should be simple in construction and adapted for universal use as a source of power. It has been manufactured since that time principally in small sizes, in connection with electrical specialties. One interesting application of the motor was shown in our issue of Dec. 21, 1899. The remarkable speed range inherent in the motor was discovered only gradually; it was finally recognized that the motor is eminently adapted for shop driving, as brought out in the preceding, and a new factory was built to manufacture it for that market. Up to the present sizes from ½ to 50 HP. have been built, but larger motors will soon be manufactured.

STEAM LOCOMOTIVES TO RUN AT 100 MILES per hour are said to have been ordered by the Russian State Railway, from the Cassel Locomotive Works. The locomotives, of which two have been ordered, are to be run as an experiment on the military line from Marienfeld to Zossen, where the experiments with high-speed electric cars were made last year, which resulted unsuccessfully. According to a correspondent of the London "Engineer," these locomotives are to weigh 78 tons without the tender when ready for service, and are to be capable of hauling a load of 100 tons at a speed of 81 miles to 93 miles per hour. With a load of 90 tons, continues the correspondent, "the new engines must be able to make a speed of at least 125 miles per hour." As it is manifestly absurd that so small a reduction in load could make such a difference in speed, we venture to guess that 100 miles per hour is the mark really aimed at. The new machines are to be ready for service by May, 1903.

WOMEN CIVIL ENGINEERS may figure later in the profession. In any event, three women have signified their intention of taking the civil engineering course at Cornell University for next year. They are the first to take the Cornell course.

CIVIL SERVICE EXAMINATIONS will be held on Aug. 29 and Sept. 3 by the Municipal Civil Service Commission of New York City for electrical engineer and mechanical draftsman, respectively. The salaries of the positions are $3,000 and $1,200. Full particulars may be secured from S. William Briscoe, Secretary, 346 Broadway, New York City.

A NEW ENGLISH RAILWAY RECORD has been established within the past month in the shape of a permanent train just put on between London and Birmingham, which is to make the distance daily in just two hours, or rather, in 1 hr. 55 min. whenever the engine-driver "can manage this without resorting to any exceptional velocity." The distance between London and Birmingham is 113 miles, and to cover it in two hours calls for an average speed between stops of 59.5 miles per hour. The regular train will consist of five double-truck cars, or about 130 tons behind the tender.

THE CUNARD LINE STEAMER "CARPATHIA" has just been launched at the yards of Swan & Hunter, Ltd., at Wallsend-on-Tyne. The vessel is intended for mixed passenger and freight traffic, being provided with accommodations for about 200 saloon and about 600 third-class passengers. The principal dimensions of the vessel are: Length, 558 ft.; breadth, 64.3 ft.; depth, 40 ft. 6 ins.; gross tonnage, about 12,900 tons. There will be four complete steel decks. The space between the lower and the main deck forward will be fitted as a cold-storage room for carrying dressed beef, etc. The vessel will have two quadruple-expansion engines, and seven boilers fitted for forced draft. The speed is expected to be about 15½ knots.

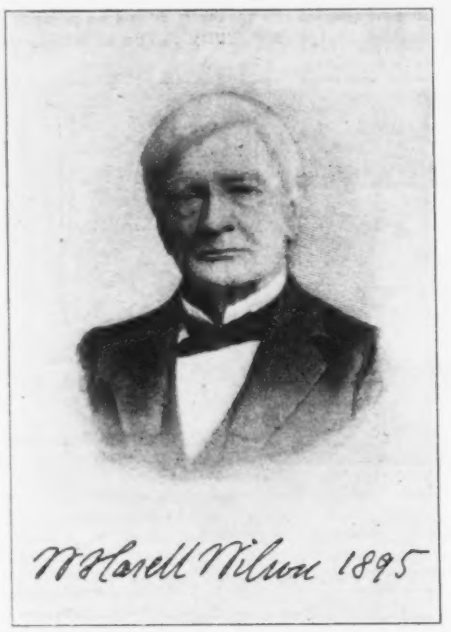
WILLIAM HASELL WILSON.

William Hasell Wilson, one of the earliest and most prominent of American civil engineers, died in Philadelphia on Aug. 17, in the 91st year of his age. Mr. Wilson was the son of Major John Wilson and Eliza Gibbes, and was born in Charleston, S. C., Nov. 5, 1811. His grandfather, Lieut. John Wilson, of the 71st Highlanders, was actively engaged here during the War of the Revolution, and was for a long time on engineering duty as an assistant to Major Moncrieff, of the Royal Engineers. The father of Lieut. Wilson was James Wilson, of Stirling, Scotland; also an engineer and architect. At the close of the Revolutionary War, Lieut. Wilson married a daughter of Dr. Robert Wilson, of Charleston, S. C.; but he later returned to Stirling. The mother of William Hasell Wilson was the daughter of William Hasell Gibbes, a Captain of artillery in the South Carolina troops of the Revolution, and a great-grandson of Robert Gibbes, Colonial Governor of South Carolina in 1710-12.

Upon the death of Lieut. Wilson, of Stirling, his widow returned to Charleston; and her son John, who had been educated at the University of Edinburgh, became an engineer and surveyor. When the War of 1812 was inaugurated, John Wilson, under Gen. Thomas Pinckney, planned and constructed the fortifications at Charleston, and at the close of the war he was commissioned as Major in the Topographical Corps, U. S. A., but he resigned after a few months' service. From 1818 to 1822, Mr. Wilson was "civil and military engineer of South Carolina," and after practicing his profession in Charleston for several years, he removed with his family to Philadelphia in 1826. In 1827, Major Wilson was appointed by the Canal Commissioners of Pennsylvania Chief Engineer for the survey, location and construction of a railway from Philadelphia to the Susquehanna River. Ill health compelled him to resign this position before the completion of the work, and he died in 1833.

His son, William Hasell Wilson, was educated at private schools and at the Charleston College; in 1826-27 he was tutor at the High School of the Franklin Institute in Philadelphia, and at the same time took private lessons in mathematics and drawing. In June, 1827, he was a member of a surveying party under his father, serving as chainman; and with him was John Edgar Thomson, who later became Chief Engineer and afterwards President of the Pennsylvania R. R. In 1828, Mr. Wilson was rodman on the location of the Philadelphia & Columbia Ry.; he was an Assistant Engineer in 1829-30, and was Principal Assistant Engineer, on the eastern 40 miles of the road, from March, 1831, until the completion of the work in October, 1834.

In 1835, under Moncure and Wirt Robinson, Mr. Wilson was Principal Assistant on the final location and construction of the Second Division of the Philadelphia & Reading R. R.; extending from Bridgeport, opposite Norristown, to a few miles east of Pottstown, Pa. This work was finished in June, 1838, and he then became Chief Engineer of the "Gettysburg Extension" of the Pennsylvania State Railroad. The business depression, commencing in 1839, caused the suspension of this and other public works, and in 1841 Mr. Wilson turned his attention to farming, and he became so interested in this new pursuit that he continued in it until 1858.



In 1852-3, however, he was in the service of the Pennsylvania R. R. Co.; and in 1854 he was Chief Engineer of the Philadelphia & Westchester R. R., and finished that line as far as Media. On Aug. 1, 1857, Mr. Wilson was appointed Resident Engineer of the Pennsylvania R. R., between Philadelphia and Columbia; and in 1859 he was placed in charge of the entire line to Pittsburg with its branches; in 1862 his title was changed to that of Chief Engineer, and he had as assistants an Engineer of Bridges and Buildings, and a Resident Engineer on each of the three divisions of the main line and on the Tyrone Division. In November, 1873, Mr. Wilson was made President of the Philadelphia & Erie R. R. Co., but he still continued with the Pennsylvania Co. under the title of Consulting Engineer. In 1874, he resigned the presidency of the Philadelphia & Erie Co., and was placed at the head of the newly-organized Real Estate Department of the Pennsylvania Co., and he held this position until 1884, when he was again elected President of the Philadelphia & Erie R. R. Co., and of several other lines controlled by the Pennsylvania R. R. Co. Mr. Wilson resigned these positions in 1894, excepting only the presidency of the Belvidere Delaware R. R. Co., which he held until his death.

Mr. Wilson was an Honorary Member of the American Society of Civil Engineers, and Honorary Member of the Engineers' Club, of Philadelphia. His sons, John A. and Joseph M. Wilson, were both prominent in the engineering profession, and the latter survives him. We understand that the fifth generation of engineers has its representatives in the Wilson family.

ELECTRICAL EQUIPMENT OF THE C. & C. SHAFT OF THE CONSOLIDATED CALIFORNIA & VIRGINIA MINING COMPANY.

By Leon M. Hall, Consulting Engineer.

When the mining properties on the Comstock Lode were first developed, operations were carried on by means of steam power, wood being used as the fuel. This was very costly on account of the scarcity of wood. The milling of the ore was until quite recently done at a distance of some 15 miles from the mine, at a point on the Carson River, where cheap water power could be obtained. About two years ago the question of electrical transmission for the purpose of supplying power for deep-mining operations on the Comstock Lode was taken up, and since that time extensive hydraulic developments have been carried out at Floriston, Cal., on the Truckee River. Power is now transmitted from this point 35 miles to the mines in Storey County, and a dozen or more of the properties have been equipped with electrical machinery. Among these is the C. & C. shaft of the Consolidated California & Virginia Mining Co., which has a world-wide reputation as a bullion producer.

The power plant on the Truckee River is about two miles east of Floriston. The river is dammed just below the Floriston pulp and paper mill, and the water is conveyed about 600 ft. through a canal, and then 8,600 ft. through a wooden flume 6 ft. 8 ins. high and 10 ft. wide, to a point directly above the generating station. It is then conducted through two wooden stave pipes 160 ft. long and 6 ft. in diameter, to the wheels, upon which there is a head of 84½ ft. There are two pairs of 27-in. horizontal McCormick turbines direct-connected to Westinghouse, 3-phase, 60-cycle generators of the revolving armature type. These generators are separately excited by two 22½-K-W. direct-current machines. The wheels will each develop 1,400 HP. at 400 r. p. m., with the above head of water. They are regulated by two type "B" Lombard governors.

FIG. 1. BUILDINGS AT THE C. & C. SHAFT OF THE CONSOLIDATED CALIFORNIA & VIRGINIA MINING CO., COMSTOCK MINES, NEVADA.

Current is generated at 500 volts, and is raised to 24,000 volts by means of six 300-K-W. Westinghouse oil-insulated transformers, at which potential it is transmitted 33 miles over a double circuit of No. 4 hard-drawn copper wire, to the

substation at Virginia City. The line is composed of square redwood poles 30 ft. in length, with pine cross-arms and locust pins, upon which are mounted 7½-in. Locke insulators. The telephone circuit is carried on the same poles by oak brackets with pony insulators.

At the substation at Virginia City the potential is lowered to 2,300 volts by means of six 450-K-W. Westinghouse oil-insulated transformers, and at this potential current is distributed to the various

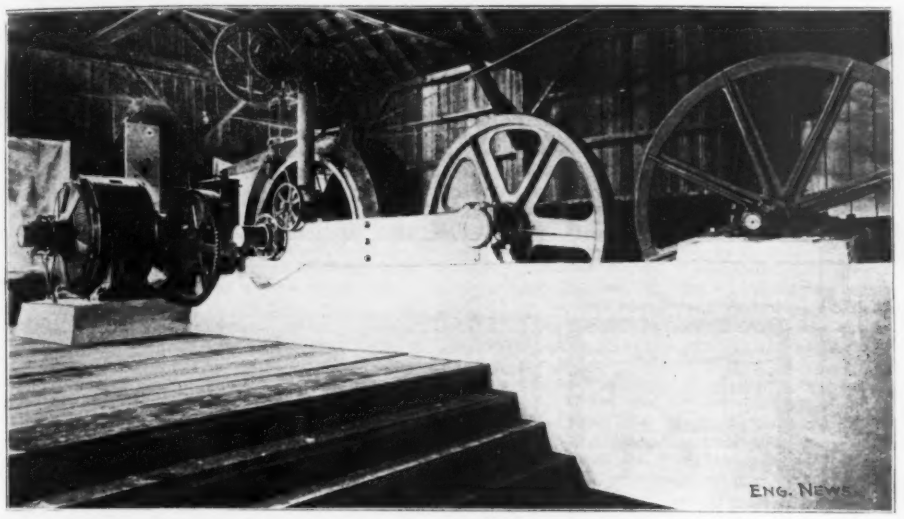


FIG. 2. 200-HP. ELECTRIC MOTOR DRIVING CONTINUOUS HOIST AT C. & C. SHAFT.

mining companies. The distribution circuits are composed of weather-proof wire and are designed for 4% drop under full load.

The plant has been in continuous operation since October 20, 1900. The Truckee River General Electric Co. sells power to the various mining companies at $7 per HP. per month, the amount used being based on a maximum peak load of two minutes duration. This, with other conditions, has made advisable the installation of machinery of the very highest grade and the introduction of some features which are rather unique in character. In the C. & C. shaft at Virginia City every precaution has been taken to secure thorough reliability and the highest efficiency.

The electrical machinery in operation on the surface at this shaft consists of the following apparatus:

A 200-HP. type "F" 2,200-volt variable speed 3-phase Westinghouse induction motor, geared to balanced electric hoist.
A 100-HP. type "C" 2,200-volt Westinghouse induction motor, belted to a 16½-in. x 30-in. single-stage air compressor.
A 30-HP. type "C" 440-volt Westinghouse induction motor, operating circular saws.
A 15-HP. motor of the same type, driving tools in the machine shop.
A 10-HP. type "C" motor, operating a Blake rock breaker at the ore bin.
Three 15-K-W. indoor type Westinghouse transformers, transforming from 2,200 volts to 440 volts.
One 5-K-W. Westinghouse lighting transformer, transforming from 2,200 volts to 110 volts.
Two Manhattan arc lamps.
Fifty incandescent lamps, together with necessary lighting arresters, fuse blocks, cut-outs and switches.

The apparatus underground consists of the following:

A 15-HP. type "C" induction motor, operating at 440 volts and driving a fan on the 250-ft. level.
Two 10-HP. motors of the same type, driving fans on the 1,950-ft. and 2,150-ft. levels.
Three 225-HP. type "C" motors, operating at 2,200 volts and geared to three duplex double-acting Riedler pumps located on the 2,150-ft. level.
Three 10-K-W. type "O. D." transformers, transforming from 2,200 to 440 volts, located on the 1,750-ft. level.
A 3-K-W. lighting transformer, transforming from 2,200 volts to 110 volts, on the same level.
Three 15-K-W. type "O. D." transformers, transforming to 440 volts, on the 1,950-ft. level.
Two 5-K-W. "O. D." lighting transformers, transforming from 2,200 volts to 110 volts, on the same level.
Three 10-K-W. transformers, transforming to 440 volts, on the same level.
A 5-K-W. lighting transformer, transforming to 110 volts, on the same level.

These are all Westinghouse transformers, and supply the motor and lighting circuits within the mine.

There are 250 16-c. p. incandescent lamps scattered through the workings underground. A No. 6 B. & S. 3-conductor lead-covered cable armored with iron wire extends from the surface to the 2,150-ft. level, and a No. 0 3-conductor cable to the pumps on the same level. The weight of the No. 6 cable is 6 tons, and of the No. 0 cable 10 tons. The cables were lowered down the shaft by means of the hoisting rope and then securely clamped to the wall plates. At each station a water-tight junction box is used, and the lead covering is sweated into a tight-fitting sleeve located in the side of the box.

The power is brought into the works over two separate circuits, each of which is provided with a single pole switch at the entrance of the building and, also a Westinghouse integrating wattmeter with its transformer. The pump circuit is further equipped with an ammeter, a frequency indicator, a power-factor indicator and a static ground detector. Oil-break switches are used on the cable circuits and upon all of the 2,200 volt motors. The small motors, both on the surface and under ground, are equipped with autostarters, quick-break switches and slate base fuse-blocks. Some of these machines are located in warm places and operate under severe conditions.

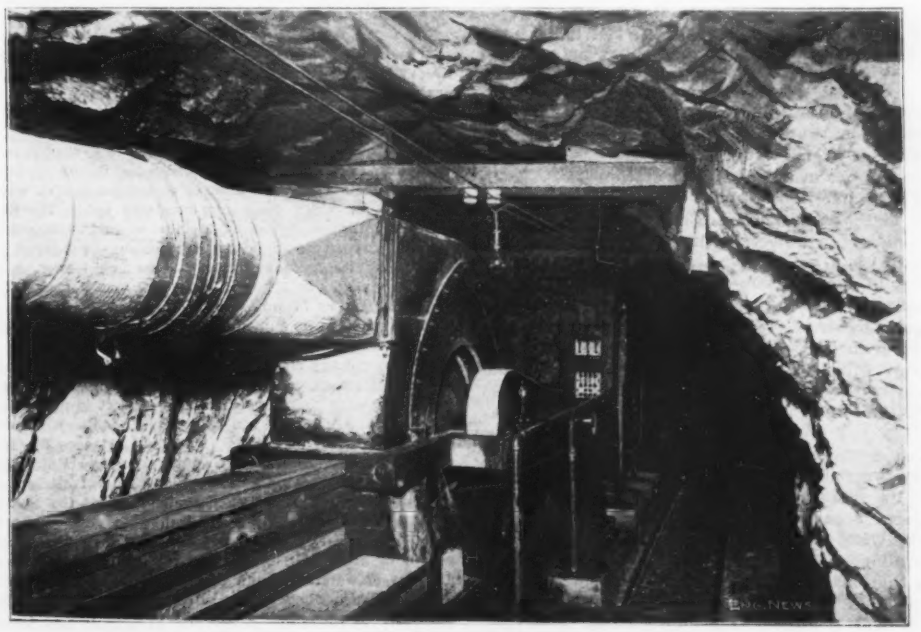


FIG. 3. 10-HP. ELECTRIC MOTOR DRIVING BLOWER ON 2,150-FT. LEVEL.

The entire installation is wired with lead-covered cables or with rubber-covered copper wire mounted on glass insulators or porcelain knobs. The greatest care is used in installing the wiring, with the result that it is safe and gives absolutely no trouble. Candles have been entirely discarded, incandescent circuits having been carried directly to the working faces and into the stopes. The current is taken into the mine at a potential of 2,200 volts, through the cables above mentioned, and the potential is lowered in the mine by transformers, which are located as near as possible to the point of consumption.

The compressed air plant, supplying air for drilling, a number of underground hoists and the hydraulic pump, consists of a 16½ x 30-in. Rand & Waring single-stage air compressor, driven at 73 r. p. m. by a 100-HP. type "C" Westinghouse motor. The motor speed is 580 r. p. m., which is reduced by a counter shaft with wooden-rim pulleys and rubber belting. No automatic regulator is used at the present time, as the compressor is working to its full capacity and the motor is developing 96 HP.

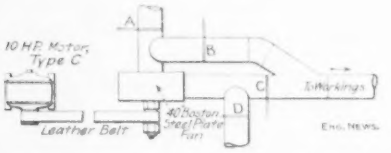


Fig. 4. Arrangement of Dampers for Reversible Fan.

(As an exhauster: Open Gates B and D, close A and C. As a blower: Open Gates A and C, close B and D. Motor and fan in same direction.)

The electric hoist is a decided departure from usual practice in deep mine-hoisting plants, and embodies what is commonly known as the balanced, continuous or tail-rope system. This was adopted in order to reduce the cost of operation and, also, the size of the motor to the lowest size compatible with the duty required, viz.: to hoist 500 tons daily from the 2,500-ft. level by means of double-deck cages carrying 3,600 lbs. of rock. The hoist consists essentially of a main driving drum and an idler, around which is wrapped a 1⅛-in. plow steel wire rope. The rope passes down one compartment, around a movable tail sheave and up the other. One cage is inserted between the ends of the rope and the other cage is fastened to the rope by heavy iron clamps. The main driving drum is geared to a 200-HP. type "F" variable speed Westinghouse 3-phase induction motor, which operates at a maximum speed of 580 r. p. m., moving the cages through the shaft at 1,250 ft. per minute. The speed of the motor is readily controlled by means of variable resistances inserted in the secondary winding, but external to the motor itself. The variation of the resistance is accomplished by the use of a special controller resembling an ordinary street-car controller; the primary circuit is controlled by means of an oil-break switch. The hoist is equipped with heavy post brakes, hydraulically operated, and the machine is handled with remarkable ease. In tests that have been made these hoists show a net efficiency

of about 75%, counting all electrical and frictional losses.

The pumping plant consists of three duplex double-acting 6 11-16 × 24-in. Riedler pumping engines, located on the 2,150-ft. level. These pumps take their water supply from a tank on the east side of the shaft just below the 2,150-ft. station. Each pump is separately driven by a 220-HP., type "C," 2,200-volt Westinghouse induction motor, and has a capacity at 110 r. p. m. of 1,500 gallons per minute to the height of 450 ft., or to the Sutro Tunnel level. The motors run at a speed of 495 r. p. m., the necessary reduction being obtained by the use of cut gearing with stepped teeth. The total capacity is 4,500 gallons per minute and it is intended to take the water from the hydraulic elevator as long as it is used as a sinking pump.

The pumps are located in a station 30 ft. north of the shaft. This station is cut from the solid rock and is 18 ft. × 17 ft. 8 ins. in section and 110 ft. long. It is timbered with 14 × 14-in. pine timbers, with 3-in. planking. A drift 5 ft. × 10 ft. 6 ins. in section connects it with the shaft and ventilation is obtained by means of a small electrically-driven blower. The motors are all wired with lead-covered cable and the station is lighted with incandescent lamps. A 10-ton hand crane travels the entire length of the station, so that the labor of handling and installing machinery has been reduced to a minimum.

This plant is undoubtedly one of the best and most complete mining installations in the world, and its operation has been entirely satisfactory, both in regard to economy and reliability. Up to the time when electrically-transmitted power was adopted, the cost of motive power was never less than $20 per HP. per month, while under existing conditions it is reduced to $7. The entire plant was installed according to the plans and specifications of the writer, and under the able direction of Supt. Jos. R. Ryan.

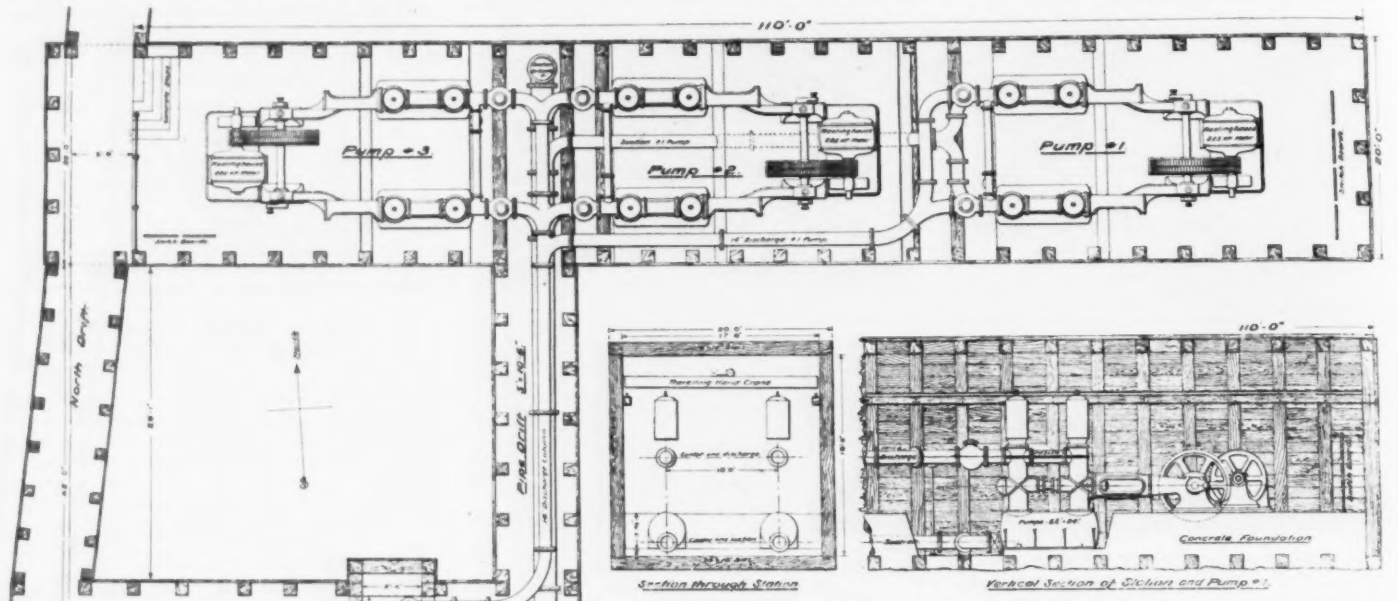


FIG. 5. ELECTRIC PUMPING STATION AT 2,150-FT. LEVEL.

SUCCESS IN LONG DISTANCE ELECTRIC POWER TRANSMISSION.*

By F. A. C. Perrine,† D. Sc.

Two elements make success in the long-distance electrical transmission of Power—Continuity and Regulation. Perhaps these are the most important elements in any electrical undertaking and are the most obvious, but in attaining our ideal in long-distance work, there lurk pitfalls about these two elements unknown in other fields of the art. From the outset in the original studies, and down the line to the last switch and insulation, lie unknown problems and problems known, but unsolved. It is the field of the thoughtful, independent engineer; the ground is stony and fit traveling only to the most resourceful.

Hydraulic development is one of the oldest arts, but the amount of human ignorance concerning hydraulic problems and conditions is appalling. Records may have been kept of the rivers whose waters are navigable, or whose rapids and falls are along the railroad lines, or in the manufacturing villages; but an investigation of the records available concerning important powers, even a few miles out of the regular lines of travel, would surprise you by their lack of accuracy and detail. Rainfall records have been kept for generations for the benefit of agriculturalists, but the watershed of no one power stream of my acquaintance has even been completely covered in its essential details by rainfall records.

The water available at any one point where the rainfall can be approximated will be estimated by different engineers from 15% to 70% of the total fall, and, apparently, each will be justified by engineering precedents. Such possible variations call for the exercise of caution, judgment, and experience in reaching conclusions.

Nor is there less uncertainty in regard to hydraulic construction. The present year has seen the failure of dams built by engineers of the highest reputation and at water pressures for which they were supposed safe. The flow in canals, ditches, flumes, and pipes, is still a subject of dispute, and errors in design are continually leading to serious results for the investor. The one lesson to be drawn from all this is that, if continuity only means success, the studies in water-power location must be made with unusual care, and ample, though never ridiculous, margins allowed in the estimates.

Perhaps the day may come when the civil engineers will establish their empirical equation in hydraulics on a sure basis, but until that day is reached—and it is not near—the hydraulic engineer can never cease to be a student and most careful observer. In almost all cases the formulae of engineering have a sound experimental foundation, but the error has actually been made of attempting to apply results obtained from the gagings of the Mississippi to small rapid rivers, and even in some cases to lined canals and timber flumes, and an equal error committed of attempting to apply the results obtained from the flow of water in 8 and 10-in. pipes to great conduits and even open flumes. No smile should arise over the absurdity of these errors, for every state in the Union has instances of them, and no year in the past twenty but has seen them committed to the waste of thousands and hundreds of thousands of dollars. The records for the past five years at one of our most respected testing flumes are at fault on account of an altered pressure pipe and an uncorrected formula. Success comes to the cultured engineer who keeps close to his borrowed data and who solves for himself the unforeseen problems.

I mean by "Culture" what Matthew Arnold means when he says that culture is "A pursuit of our total perfection by means of getting to know, on all the matters which most concern us, the best which has been thought and said in the world." Such an engineer with such an ideal will be a safe guide and his studies will establish on a firm basis our transmission undertaking.

But we are not concerned to-night with the errors of the civil engineer, or with his unsolved problems so much as with what is new and with what is gradually getting to be known in electrical problems. While these are no more important nor more interesting than the hydraulic problems, they are attracting more attention and perhaps it is in apology for our electrical ignorance that I call attention to hydraulic difficulties and ignorance. It is true that in no other art can so accurate calculations be made as in electrical engineering, but there are many facts and constants for our equations still unknown. Even in the electrical art there is still an unknown, and I suppose that no one of us will live to see the discovery of even all the knowable our art contains. I am reminded now of the beautiful equation for the dynamo machine presented twenty years ago by Clausius, which contained a round dozen of unknown constants, and though we have since discovered the values of some of his constants, others have been found to have been variables, and we are still studying the problem and searching for the others.

Regulation in direct current work is a simple problem. Its laws are all known; at every lamp it is quite easy to predict the variation of voltage. The same laws control whether the lines be long or short. In his transmission plants Thury has met no new difficulties, but has effected regulation at ten or twenty miles, just as he would have done had the delivery been made only in the next room to his dynamos. Resistance is always resistance and his dynamo characteristics remain unaltered by its increase. He deals only with current, voltage, and resistance and encounters problems simple even to Faraday, Henry, or Ohm.

REGULATION IN ALTERNATING CURRENT PLANTS.

It has been said very truly that the introduction of the alternating current raised the electrician above the rank of the artisan. With these currents he is no longer dealing with a few simple independent quantities connected by a primary rule, but must now consider many new elements, some constants and some variables. At every step capacities and self-inductions enter into the solution in complex and involved relations. Regulation can no longer be simply determined for each part of the system independently, and the regulation of the whole obtained by a consideration of the parts separately. Self-inductions and capacities affect each other, and the generators and lines, as well as the transformers and motors must be chosen or designed with this interdependent relation in view. A simple case illustrates this beautifully.

When the operation of the transmission supplying current to the city of Stockton, California, from the power plant at Mokelumne Hill, 46 miles away, was first begun, a curious state of affairs was observed. In operation of the lines alone, the current required on the 2,200-volt side of the step-up transformers was 60 amperes; with the step-down transformers connected, the current fell to about 50 amperes, and when a 100 K-W. motor was put into operation the current was only 55 amperes. The transmission was designed to be at 25,000 volts, but at the delivery end of the line the voltage was found to be 27,200 volts, and finally the motors consumed full current when running at no load and not much more when operating with full load applied.

I think that all will agree that here are problems enough for one small instance of the difficulties in the regulation of a long-distance transmission plant.

The lines in this case had been calculated for an 8%

*A paper read before the Boston Society of Arts and printed in the "Technology Quarterly."

†President of the Stanley Electric Mfg. Co., Pittsfield, Mass.

loss of energy for transmission of 1,000 K-W., and capacity played the most important part in these pranks of voltage and current. With the lines alone, the capacity was so great as to absorb an apparent energy of over 100 kilo-volt-amperes. This is reduced when the transformers are connected and some real energy begins to flow and the self-induction of the step-down transformers neutralizes some of the capacity of the line.

When the motors are connected, the real energy is increased and the self-inductances of the various parts of the system become more important.

The apparent rise of voltage along the line illustrates the interdependence of the whole system even more clearly, for it is only in a very small part due to the line itself, or rather, while due to the line, it occurs in the step-up transformers and not to any extent along the line.

It is not uncommon to attribute such an effect to resonance, which really only rarely becomes important; in reality, the regulation of the transformer produces this effect. With any transformer fed with a constant voltage at the primary, the secondary voltage falls with non-inductive load and falls still further if an inductive load is applied, but if the load is a capacity load, the secondary voltage rises instead of falls. In this case, therefore, the step-up transformers were delivering a 10% higher voltage to the line than their transformation ratio accounted for, which necessarily disturbed the regulation seriously. This trouble became even more serious when a heavy induction-motor was later operated by the same plant. The load on the motor accounted for a fall of potential amounting to 4%, but the inductance produced a drop of 10% at least; and, as the rise of voltage on the line at no load was as much as 10%, it may at once be seen that the voltage varied when the motor was connected from 10% above normal to 10% below, and thus a variation exceeding 20% was produced in place of a variation of 4% for which the load allowed.

The effect upon the synchronous motor was also due to this ever troublesome capacity. The generators were giving nearly a true sine wave of E. M. F., while the motors were designed for a peaked wave. The line capacity so affected the generator wave that the difference between the motor and generator became great, and for part of each wave the motor was absorbing power, and for its remainder delivering power, so that a great current was always flowing.

In this particular case these troubles were corrected by the introduction of a heavy self-induction across the ends of the line which neutralized the line capacity; and this self-induction was used until an inductive load was connected in the shape of induction motors, which rendered the use of an extra self-induction unnecessary.

Whenever this arrangement can be thoroughly carried out and the capacities and self-inductions connected to any line can be evenly balanced, the alternating problem can be reduced to the simplicity of the direct current problem and a long algebraic equation can be abandoned in determination of the expectations. This possibility is beginning to be appreciated and regulation attained in long-distance transmissions which could not otherwise be hoped for.

There is little electric motor service which calls for absolutely continuous power. Most motor plants, which are said to be operating "day and night," shut down at meal times and are rarely operated more than twenty hours of the twenty-four, and even where the operation is continuous through the day, there is a cessation of operation on Sundays and holidays. For this reason, it is difficult to satisfactorily balance the capacity of the line against the inductance of any load. The line capacity current is constant and is continuously in evidence so long as the voltage is applied to the line; indeed, it varies only with the voltage and periodicity. Its importance increases as the load diminishes, for when the load is heavy it is not only completely overcome by inductance, but also is rendered unimportant by reason of the presence of a large current in phase with the electro-motive-force. During the time when all loads are diminished, the disturbance of regulation by reason of the presence of a line capacity current is most apparent, and consequently the counteraction of that capacity effect, by a heavily inductive load which is off during these same periods, is a remedy which only accentuates the disease. This was illustrated in the case described above where a severe induction load depressed the voltage and its removal allowed the full rise due to line capacity.

In the case of the Standard Electric Company's transmission and that of the Bay Counties Power Co., in California, where transmission of approximately 150 miles at 50,000 volts and 60 cycles are undertaken,* the charging current is approximately 40 amperes; or, in other words, the line requires the full capacity of a 2,000 K-W. machine for charging it as a condenser. The complete neutralization of this great capacity effect would require the continuous working of something in excess of 5,000 K-W. of induction motors with average normal power factors.

Up to the present time no load on the Bay Counties lines has ever been applied which is capable of neutralizing this capacity effect. The attendants at the power house are practically unable to have much knowledge of the loads actually applied on the lines except by observing the wattmeters or the wheel nozzles, since the current from no load up to a load of several thousand kilowatts remains practically constant. As there are many branching lines supplied from this system, it is impossible to operate other than with constant E. M. F. at the dynamos, and the regulation of the long lines is affected by the capacity, which influences everything from the step-up transformers to the last motor.

In order to overcome the troubles due to this source, the Bay Counties Company have arranged to place upon their lines impedance coils capable of practically neutralizing the entire capacity of their long lines; and, as soon as these are installed, one of their greatest difficulties in obtaining satisfactory regulation will be removed. With the capacity of the line neutralized, it then becomes necessary to keep the load as nearly non-inductive as possible by continuous care in the balance of synchronous against induction motors in the operation of loads.

It is a great mistake for an engineer to become an advocate of one motor to the exclusion of the other type. Both synchronous and induction motors have their spheres of usefulness, and practically every long-distance transmission demands for its satisfactory regulation the use of both types. Where the powers are small and the loads easily started, the simplicity of the induction motor and ease of installation renders it especially suitable, but as their numbers increase, the effect of the lagging currents they absorb becomes important in disturbing regulation, so that it soon becomes necessary to neutralize this lagging current either by the introduction of condensers or of synchronous motors.

With a synchronous motor it is possible to counteract the effect of large and variable inductive loads, and, when they are installed in the substation at the delivery end of the line, a ready and satisfactory means of controlling the voltage, whether it is disturbed by inductive or non-inductive loads, is provided. Practice with these machines indicates, however, that they are still very useful if installed at points out of control of the substation attendants, provided only that their power of controlling voltage be not used maliciously, since they are generally most useful when the exciting current is adjusted to a minimum; a condition for which instructions are easily issued and of which the reasonableness appeals to the most ignorant attendant.

Much has been written and said of the resonant condition of a line, but up to the present time practice in the installation of plants and connection of motors, transformers, and other devices has not led to important interference from this source. What is called the resonant line, or distortionless line, can be obtained in two ways, either by the connection of capacities and inductances in series, or by their connection in parallel. In the first method of connection there is a very serious rise of potential at the respective terminals of the capacities and inductances, but with the parallel connection no such rise is found. The series connection of capacities and inductances is rarely used and principally on account of the difficulties likely to be encountered on account of these phenomena. The exact balance of inductances against the capacity of a line fifty or one hundred miles long, capable of supplying some thousands of kilowatts, would result in a voltage rise of not less than ten times the value of the normal; and, when one considers that this normal may be anywhere between twenty-five and fifty thousand volts, it is easily seen that such resonance may be formidable. Such an effect is sometimes actually encountered in the operation of switches on lines where considerable cable lengths are used in feeding highly inductive apparatus. In a recent case an arc within a partially broken cable feeding rotary transformers, by raising the periodicity and producing apparently a resonant condition, caused the effect of most violent short circuits, blowing fuses with great violence and destroying both fuse holders and switches, currents appearing entirely beyond the capacity of the generating apparatus to maintain. When the proper inductances are connected in parallel, however, their action is beneficial to regulation and easy to handle, as has already been explained.

What has so far been said covers fairly well the question of purely electrical problems of regulation, and to call your attention to the essentials of the problem, it only needs the summary that regulation in a long-distance plant is attained by—

First. A wide possible voltage variation in the generators, with generators and transformers both designed, not for good non-inductive load regulation, but for good inductive load regulation.

Second. Lines designed for the smallest possible capacity current without reference to any attempt at balancing the line capacity against the load lag.

Third. The use of reactance coils for balancing the constant capacity of the line.

Fourth. The use of synchronous motors as a variable capacity for balancing the variable inductance of the line and the inductive motor load.

CONTINUOUS OPERATION OF ELECTRIC PLANTS.

Of the elements of design which involve most nearly the question of continuity, supreme importance attaches to the insulators, the switches, and the lighting arresters.

To be sure, the entire problem of continuity is also the whole problem of design. Everything must be built to withstand the strains and the methods of accomplishing this are neither easy nor obvious; many of the well-established methods of conveying and controlling water must be abandoned in favor of those which are more enduring. Open ditches and flumes are giving way to enclosed and lined trenches and tunnels.

For station structures, the extreme of strength and fireproof character must be resorted to and the whole transmission line must be built for the greatest permanence. Spans are shortened even in some cases to only one-third of that used in telegraph and telephone construction. Heavier poles are employed, most carefully set, and braced against even the slightest increase of strain. Rights of way are secured and cleared so that these transmission lines stand up against the storms and fires that lay waste the countryside.

INSULATORS.—But returning now to the purely electrical part of the problem with which we are most directly concerned for the present, and directing our attention to the insulators, which present the first and most difficult problem, we find at the outset a royal battle waged between the insulating properties of glass and porcelain. In this country glass has for many years been the king of the insulators; abroad for an equal period of time, porcelain has remained pre-eminent.

For potentials up to about 25,000 volts, where an insulator of 7 ins. diameter is sufficient, there seems not much reason for the employment of anything except glass, unless the lines reach a size about ½-in. in diameter, when its strength is deficient. For these lower potentials and lighter lines the good properties of glass are easily summarized. In the first place, it is cheaper by far; while not so strong as porcelain, it is, as has already been said, sufficiently strong for the purpose; its inspection is easier and surer, since it requires only a visual examination and a few taps of a hammer to ascertain its soundness in place of the tedious high potential test necessary in the examination of porcelain. But having said this much, all has been said that is possible in favor of glass.

It is not true that glass is a better insulator than sound porcelain, nor is its surface so good in damp weather against surface leakage. The mechanical strength does not equal one-half that of porcelain, as has been proved by a long series of mechanical tests performed by dropping a steel ball from a height upon insulators of the two materials; temperature also affects it much more than porcelain and it is often found to crack simply from the effect of extreme changes of temperature.

The insulators for high voltage lines must be very large, for the reason that with a striking distance through the air of from 4 to 6 ins., great gaps must be provided in the path of the current. But above all a great creeping distance is essential. Insulators that are a perfect protection in the hardest rains fail utterly in clear weather when covered by smoke and soot, which allow small amounts of currents to escape and char away the pins or crossarms.

The compound insulator is very attractive, for the reason that it is easier and cheaper to make and handle two or three small parts rather than one large one, and in some cases the additional advantage has been sought of securing the good properties of both glass and porcelain by making parts of an insulator of each; but there is both a theoretical and practical fallacy in this type of design. In the first place, no dielectric is so strong as one entirely homogeneous. As the stress is passed from glass to porcelain, or vice versa, at the two surfaces the stress piles up as it were, and it is better if one believes in glass to rely upon it; or, on the other hand, to show faith in the porcelain used by employing it entirely.

From the standpoint of practice the insulator which must be cemented together is troublesome. The shrinkage of the mastic leaves voids and produces strains; if cement be used, its slowness in hardening delays the work and requires large areas for setting out to harden any considerable number of insulators. The one other mastic in use is molten sulphur, which, while better as a mastic than cement, is still more liable to crack the insulators while they are being joined, and finally when exposed to light and air, frequently decomposes on the surface, producing sulphuric acid; and, finally, when current creeps over its surface following the acid, perhaps, catches fire and often results in the rupture and fall of the insulator. The insulator which will be entirely satisfactory for this use has not yet been found, but the diligent search made for it by some of our best engineers is resulting in its definition and will probably soon result in its production, not as an inspiration for a patent, but as a careful engineering conception.

SWITCHES.—Switching and switching devices are most important and most difficult. Step by step the switch has improved in the electrical art from the simple commutator used by Faraday and Henry, which generally consisted of copper wire dipping into mercury cups; until, as you know, up to the present time a great amount of ingenuity devoted to the study has resulted in the production of elaborate and beautiful electrical and mechanical mechanisms. Switching for high powers, whether at low potential and great currents or at high potential and

*Eng. News, Vol. July-Dec., 1901; pp. 230, 382.

small currents, seems to be an altogether different art from switching where the spark that may follow can do but little destruction, and its heat is readily dissipated. Almost all low-power switches are designed with the idea that a spark may occur at the break, but as the energy of the spark is small, the mass of the switch will carry away the heat, or the portion of the switch destroyed will be inconsiderable and may be easily replaced; but as soon as it becomes impossible to contemplate the destruction of a portion of the switch in the rupture of the current, switching becomes impossible by such simple devices, the whole art of switching is changed, and designs along entirely new lines must be produced. The great pneumatically controlled switches in the large power stations of New York and Boston exemplify this principle. Hardly anything in switching for small currents is similar. They are not simple switches, giants in size, but their method of operation is based upon a new principle and they involve in their construction much ingenuity and engineering study. As even the great switches with which you are familiar operate only on lines where the potential is comparatively low, the principles of high voltage switching need to be particularly called to your mind. In any high voltage transmission system as, indeed, in any transmission system, the lines and loads contain not only resistance but also capacity and self-induction. The current flowing depends upon the E. M. F., the frequency, and the constants of the circuit in an involved relation. A change in any one of these constants involves changes in the resultant current. A satisfactory switch must leave the circuit undisturbed as far as possible, and must introduce no new difficulties by reason of changed values of the constants. Furthermore, if a switch could be built which would simply instantaneously stop the current, the effect would be an immediate and great rise of potential due to the sudden fall of current through the capacities and self-inductions of the system. The open air switch which, in its essential particulars, is simply that of the ordinary knife, or snap, switch as used for low potential, draws an arc at almost full current value, which arc, being rapidly oscillating in character, effects an increase of the periodicity on the line and thereby brings about great potential rise.

We see, therefore, that a switch to be satisfactory on a high potential circuit must neither rupture the circuit too suddenly nor draw an oscillating arc. With ordinary switches in mind, the rupturing of a circuit with these requirements in view seems to be almost an impossibility; and, were there no means of introducing into the path of the switch blade high resistances which gradually reduce the current value, and finally allow the stoppage of the flow of energy after it has become small in amount, we would have to provide in insulation of our long-distance high-potential lines, materials which would withstand voltages from two to ten times the normal voltage. Of course no wire wound or carbon rheostat can be introduced into these switches, and the only resistances that are available are liquid and gaseous resistances. It is almost too soon to say that any particular type of switch has resulted from the experiments of the past two years which will be considered for all years to come the final type; but the successful work that has been done is along the line, as I have said, in the introduction of liquid and gaseous resistances. These resistances are the only ones that are high enough in value to be enclosed in the small space of a switch and which do not introduce additional complexities into the station system. The gaseous resistance is obtained in the oil switch by the carbonization of the oil as the switches open; provided there be a sufficient amount of oil above the switch contact, so that as the circuit is opened the production of gas does not blow the oil out of the switch, a very satisfactory type of switch is produced, and one which our present experiments seem to indicate, will gradually cause the rupture of a circuit without the production of excessive rise of potential.

The vaporization of metallic oxides has also been successfully used for this purpose, but when these oxides are vaporized in the switch, it is difficult to retain them within the switch and they scatter their dust through the whole station. The liquid switch is one of the comparatively new developments, and seems in many respects to be the best of all, since the liquid is always prepared as a resistance under all circumstances and does not depend upon the energy of the current to make it the imperfect conductor required. Therefore, the disadvantage of the occasional failure of the switch from too rapid or too slow production of the vapor, as is the case with the vapor switch, is avoided. An incident in the difficulty of obtaining the proper switch for high potential working is the difficulty of insulating its moving parts and operating mechanism. Insulation materials of high dielectric strength are not ordinarily satisfactory mechanical materials. They are brittle, they are hard to work, often impossible to work, and are not readily obtained in exact form. Hence, many a switch that is entirely satisfactory from an electrical standpoint proves to be a failure on account of the difficulties with its mechanical support.

LIGHTNING PROTECTION.—Lightning protection for long-distance transmission lines is, as one can readily see by the slightest consideration, of the utmost importance. Where a line passes over one hundred or two hundred miles of open country, dipping into the valley and rising to the tops of mountains, all sorts of weather conditions must be constantly encountered. A thunder storm of small area is, in summer time, a matter of frequent occurrence; and when we consider that, as the line stretches way across the country, many small areas of atmospheric disturbances may be and must be daily encountered. To be sure, as you all know, the lightning protection of a transmission line is not against strokes of lightning, but against the induced currents in the line by reason of neighboring lightning strokes. Furthermore, any transmission line must be protected against variation of atmospheric potential in clear weather. Experiments have shown that changes of elevation by a few hundred feet sometimes produce potential variation of many thousand volts and these phenomena must be encountered and handled by the transmission engineer.

One of the most effective devices that has been used is the erection of a continuous lightning rod along the entire line. For this purpose barbed wire, grounded at the poles, has been employed. In some instances this has given trouble on account of the fact that the barbed wire used was inferior in quality and erected with unsafe strains; but when the wire has been carefully erected, it is not necessarily a disturbance to the system, but a means of discharging the wire when the atmospheric potential varies and as induced current surgings are set up by neighboring lightning discharges. It is not by any means a settled principle with transmission engineers to install this barbed wire, though in the South where the lightning disturbances are most frequent, it may be said that almost every line is erected with this protective device. Where it is not used, reliance is placed altogether on the lightning arresters, through which the line may be grounded, these being installed either at the ends of the line or at the ends and at intermediate points; and even where barbed wire is employed, such additional protective devices are absolutely essential, since the circuits themselves can not be entirely freed from induced charges by any means, except enclosing them within a grounded metallic sheath, and this construction would, of course, be absurd and unmechanical.

No mechanically operated lightning arresters are ever used for this purpose in alternating long-distance transmission work, the devices employed being either of the non-arcing metal type or of a type where the air current produced by an incipient arc between the parts of the arresters blows out the arc before the machine current has an opportunity of following and affecting destruction. In some devices the combination of these two effects is to be found. These constructions of lightning arrester are old and well tried at lower potentials, but it is found that as the potentials rise, the laws which seem to govern their action change materially, and no step has been made in raising the voltage without requiring material modifications of the rules for the installation of lightning arresters. Two thousand volt calculations have been found to fail altogether on 10,000-volt lines and these again to fail when the potential was raised to 25,000 volts, and finally with the doubling of that potential, the previously ascertained rules seem to be altogether thrown to the winds, and a new system of lightning protection made necessary. The final form in which this will be received by the engineering world has not as yet been established, but the experiments which have been tried up to the present time, seem to indicate that a resistance or an impedance, or, resistance and impedance combined, must be installed in the path of the ordinary lightning arrester in order to enable the induced charges on the line to pass away readily without noticeably increasing the effective line potential and without grounding and short-circuiting the wires. The handling of this problem has been one of the last to be solved and one of the most troublesome questions involved in the engineering of transmission lines.

I have this evening been endeavoring to call to your minds the problems met by the transmission engineer and the difficulties he has to solve, which are not presented to his brethren in handling ordinary electric lines and currents; and though I may have given you the impression that there are many questions yet to be solved in order to bring about success in long-distance transmission, when success is measured by practically perfect regulation and practically absolute continuity, still it would be incorrect for me to have given you the impression that the engineers are still groping in the dark for a solution of their problems for the attainment of success as measured by the criteria I have laid down. The limitations I have placed upon the solutions that have been already applied relate only to the question as to whether present solutions are in their final form.

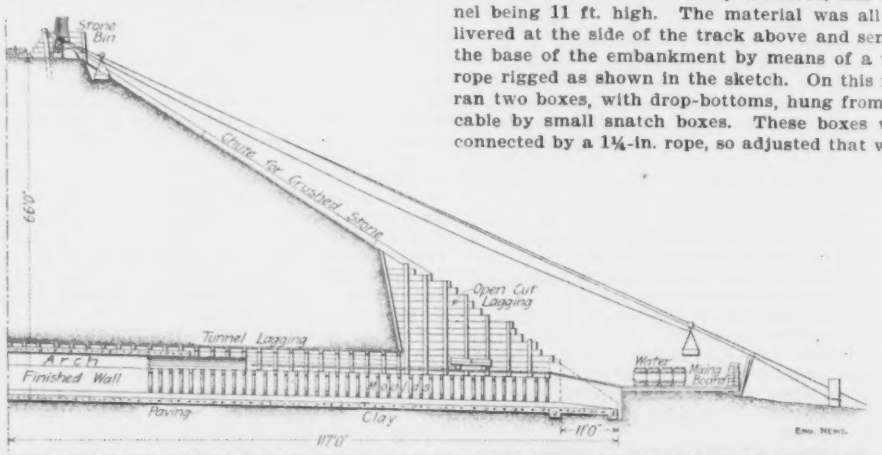
It would be a wonder of the world if, with long-distance transmission beginning in 1894, with a small plant at Portland, Me., and a small plant at Housatonic, Mass., the solution that had been reached in 1902 for the problem as extended to 200 miles were in the final form. If I have given you to-night some of the inside history of the difficulties to be encountered by transmission engineers, you would be doing me and those engineers an injustice to believe that I have been doing anything excepting calling to your attention the difficulties that have been met and the construction which still remains to be improved, while at the same time announcing the triumph in practically and successfully transmitting power up to 215 miles, and practically and successfully building at least two plants for the permanent distribution of energy at distances in each plant exceeding 150 miles.

HANDLING MATERIAL FOR REBUILDING A LONG RAILWAY CULVERT.

A culvert under a high embankment on the Western & Atlantic R. R., near Bartow, Ga., was found to be in a dangerous condition in 1901, and had to be rebuilt. In the last issue of the "Proceedings of the Engineering Association of the South," Mr. C. B. Wilson tells how the work was done. A particularly interesting feature is the plan adopted for supplying materials to the work from the railway track above.

The culvert was a double 3 × 4-ft. stone box, built of dry masonry in 1848; the embankment over it was 66 ft. high. It was decided to make an open cut in the foot of the bank on each side, extending towards the center line as far as was safe, and then tunnel under the track, the new culvert being located 30 ft. north of the old one. The new culvert was built of concrete, 5-ft. span, full centered arch, with a flat paved invert.

The total length of open cut on both sides was 77 ft., and this was lagged and braced as the cut progressed; it was 11 ft. 6 ins. wide at the bottom. A tunnel 150 ft. long was then driven under the embankment and securely timbered, this tunnel being 11 ft. high. The material was all delivered at the side of the track above and sent to the base of the embankment by means of a wire rope rigged as shown in the sketch. On this rope ran two boxes, with drop-bottoms, hung from the cable by small snatch boxes. These boxes were connected by a 1¼-in. rope, so adjusted that when one box was at the top the other stood over the concrete-mixing board at the bottom. The line passed through a double-block at the top, and the loaded box, descending, raised up the empty one. A brake-stick applied to the sheave-wheel slackened the speed as the box neared the bottom. Each box held slightly more than an iron wheelbarrow. With this simple appliance all material necessary for building this concrete culvert was successfully and cheaply handled.



HALF-SECTION OF EMBANKMENT OVER BARTOW CULVERT, WESTERN & ATLANTIC R. R., SHOWING SYSTEM OF TRANSFERRING CONCRETE MATERIALS FROM RAILWAY TRACK TO MOUTH OF CULVERT.